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FARM MANAGEMENT PROGRAMME OF THE COLONIZATION FINANCE CORPORATION[1]

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INTRODUCTION

In attempting to outline what for this purpose is called the "Farm Management Programme of the Colonization Finance Corporation", I would like to dispel, at the outset, the too common view of what such a "Farm Management Programme" constitutes. Group farm management of family farms as carried on by this organization is too often considered in a very narrow sense. The individual farmer at first approach may regard it, and the farm manager, who represents the organization, as a move to take the control of his farm operations out of his hands and place them in the hands of a sort of overseer or foreman who directs others to carry on the labor of the farm such as on large farming operations. This same idea is likely to be shared by business and industrial men, especially those whose main business consists of directing large groups of laborers or working men. I have even found men who have been employed as farm managers in our organization to hold to some extent the same idea before actually engaging in their work, a viewpoint which is changed immediately once the task is begun.

The programme of farm management, and the work of the farm manager of the Colonization Finance Corporation is much broader. Technically and scientifically speaking, farm management is usually considered one of the subdivisions of agricultural economics. Actually, as will be seen as the farm management programme of the Colonization Finance Corporation is outlined, it might well be characterized as applied agricultural economics, if such a term is permissable. The farm manager may approach his problems from a different angle than the natural scientist, or technical agriculturist, but as the plant breeder increases yields through improved varieties, and the crop specialist through improved cultivation, rotation of crops and fertilization, the farm manager must not only know the scientific principles underlying all this, but in addition be able to determine the amount of labor required and the most efficient set up of machinery necessary for performing the farm operations to secure increased yields on an economical basis. The technical agriculturist is not bound in his work always by the test of whether it pays, but the farm manager, always. Net returns and not gross returns will be the test of any successful farm management programme. While in a practical way farm management may be concerned primarily with the organization and equipment of the farm it is deeply rooted in every phase of agricultural economics.

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The Colonization Finance Corporation of Canada Limited has been set up to meet a condition created by the agricultural situation of the past ten years. The past two years of low prices, and in some sections, of crop failure, has but aggravated a situation which already existed. Of farm properties received for farm management by the Colonization Finance Corporation for the season of 1931, 28.5% were real estates, 43.8% sale agreements, and 27.7% mortgagors in arrears. In other words, 72.3% of all properties handled by the Colonization Finance Corporation in 1931 were foreclosures which had taken place during the period previous to the low prices of 1930 and 1931. Moreover, all mortgaged properties in arrears, in regard to principal and interest, reached this condition previous to 1930 and 1931.

The situation which has resulted in the organization of the Colonization Finance Corporation is not peculiar to the nine loan companies which control the Corporation. All companies loaning money on farm lands in Western Canada have had the same experience, the inability of a certain percentage of their clients to meet their obligations. The nine member companies of the Colonization Finance Corporation, with the co-operation of the Canadian Pacific Railway, represent a co-operative effort on the part of these companies to meet this problem. It goes further than mere co-operation between the companies themselves. It is a desire on the part of the member loan company, put into effect, to co-operate with its borrowers who are in financial difficulties. Experience has taught all farm mortgage companies that when a foreclosed property comes into a company's possession the land is weedy, the soil unproductive, and the buildings in a poor state of repair. It has also been found that because of a tenant's lack of security of tenure that such properties are not improved, but continue to become less productive. It has been demonstrated many times that with a tenant-operated property under the right kind of farm management, where tenants have a fair chance with some security of tenure, farms can be improved, and it is altogether possible to make purchasers out of many tenant operators who have a good chance to succeed because they are carrying on the right kind of farming programme.

Many foreclosed properties or real estates have been sold, on some crop payment plan, to purchasers whose equity in the property is very small or perhaps nil. To all intents and purposes, he is in the same position as a tenant except as to his legal status, the loan company holding the entire investment. Because of the run down condition in which these farms are usually taken over by a purchaser under the sale agreement, it is a very difficult matter for him to bring this property back into profitable production. After taking care of regular family and operating expenses, there is nothing to take care of interest and principal. Over the period of the last five to eight years very few purchasers under sale agreements are making real headway, and on such properties a closer relationship should be established between the member company, the real owner, and the occupant. The Colonization Finance Corporation's programme provides this co-operation.

Experience in dealing with real estates and sale agreements has lead to the conclusion that the same type of service and co-operation would be mutually advantageous if extended to mortgagors seriously in arrears and in danger of losing their property. It has been found that whenever an owner

of a farm encounters financial difficulties, it is very likely that the security of the loan company will depreciate very rapidly. As a result, closer co-operation with such loan accounts has been undertaken, first to prevent further foreclosures, and second, that the security back of the loan be not allowed to run down and become worthless. Most loan companies are ready to admit that formerly some very good men have lost farms and their places have been taken by inferior farmers.

It is readily admitted that the mortgage and loan companies of the Colonization Finance Corporation have undertaken this task for other than altruistic purposes. In the first place it is their belief that through the farm management programme, the farm security can be preserved, and the funds loaned safeguarded. In addition to the above, conversation with the heads of any of these companies will reveal a number of other motives behind this farm management programme.

1. They consider this programme a means of developing better farmers out of a great many people who might otherwise become failures.
2. The loaning companies consider that a distinct service will be rendered to Canadian agriculture and to the farmer on the land through the farm management programme, and the co-operating companies confidently expect due credit in course of time.

Plans and Principles underlying Farm Management Programme

It is possible to give here only the briefest outline of the plan and principles underlying the farm management programme. Not only a common sense view, but the history of agriculture itself teaches certain basic facts which are the foundation of the programme now under way. This programme recognizes that the best virgin soil ever created cannot be mined forever. Nature has a sure way of protecting itself. Even with tons of plant food stored in the soil, as might be shown by chemical analysis, after a time Nature closes her door and in unavailable form holds the balance of this plant food securely locked in her embrace. Plants called weeds only because we desire to grow other plants in their stead, are Nature's allies in preventing further robbery of an exhausted soil. If so called weeds were allowed to take their course, they would again rebuild this soil and turn it back to future generations another wonderful and virgin soil, free from all noxious weeds covered with only the natural grasses which yield at once to the demands of men. Constant killing and destroying by tillage methods of that which would again create a virgin soil, in order to unlock further plant food and conserve moisture to produce crops, leaves no longer a soil, but nothing but a finely pulverized rock and mineral, lacking in humus and moisture and subject to every gust of wind. Drifting no longer is confined to sandy soils; the heavier soils soon follow, and already precarious agriculture is faced with an additional hazard. The dust storms of the prairies are clouds of witnesses that speak for a more permanent agriculture.

The older portions of the three Western Provinces have long since passed out of the period of pioneer farming of a virgin soil, of which grain farming was the main enterprise. This soil no longer virgin, with partial depletion of soil fertility, filled with weeds and plant diseases and pests, subject to

soil drifting, has made farming extra hazardous and the cost of production excessive.

Dealing with a soil and climate in which the raising of small grains should ever be the major enterprise, the farming programme of the Colonization Finance Corporation recognizes the need for only such modifications of a straight grain farming programme as may be necessary to meet the situation created by soil drifting and weeds. Introduction of livestock only to the extent necessary to control these menaces and make grain farming possible and profitable is the underlying idea. A summerfallow system of weed control which actually does not control them must gradually be abandoned in all sections of the country except in those parts where the rainfall is not sufficient and dry farming methods must be employed. Substitutes for summerfallow are gradually being provided.

While it is highly desirable to have life on the farm as self contained as possible and establish a year round income, the introduction of livestock on such farms where the water situation warrants it is not only a step toward rebuilding the soil but more especially for the control of weeds. It has been found that more and better grain can be raised on half the acreage through seeding down and building up the soil than on a partially exhausted and weed infested soil. The cost of weed eradication by cultivation methods only is far too costly. Seeding down, pasturing, mowing for hay, not only provides measures for meeting the soil situation, making provision for revenue, but at the same time is the only effective and economical control of weeds known to agriculture. After all the weed situation is the most serious problem of Manitoba and Eastern Saskatchewan. The toll of weeds is enormous and, in dry seasons such as have been experienced lately in some sections, utterly ruinous.

It is evident that details of the various steps of carrying out the farm management programme cannot be given here. Each step which is mentioned but briefly would require more time than can be devoted to the entire subject.

Crop Maps. The first step for farm management purposes, is the making of a crop map as the farm is found. While this appears to be a very simple matter, its ramifications are many. In the preparation of cropping plans, not only must the individual enterprises or projects of each farm be considered, but also the needs for weed control, control of soil drifting, and rebuilding of the soil. Land economics and land utilization have a bearing on such plans. Many modifications in size and shape of fields for increased efficiency are necessary; adequate supplies of feed for livestock, adaptation of a type of farming suitable to the land and the operator, which provides for a proper distribution of the labor both for peak heights and throughout the year are considerations which must always govern cropping plans. The general principles set forth in a previous paragraph can govern this process but any definite crop rotation that may be set up will have many modifications to meet the situation found on the individual farm.

Inventories. Inventories of equipment, of all livestock and buildings are essential steps in establishing proper farming operations on any given farm. These inventories serve many purposes. Capital increases which modern farming requires make the problem of proper and economical

equipment very important. Balance of power and machinery and acreage must prevail if carrying charges are to be met. On encumbered farms everything must be considered from the standpoint of whether it will pay. Buildings must be adequate, but not extravagant. High priced machinery can be carried only where the acreage is sufficient to warrant the investment. Double power through tractor and horses must be eliminated. Inventories not only tell this story but in addition inventory values are a part of every farm accounting system. Payment of encumbered equipment constitutes a drain on many a farm which is hard to meet under prevailing prices. The specific problems which are met and solved by the farm manager in this connection are indeed numerous, difficult, and varied.

Accounting. The business side of farming must be emphasized in any adequate system of farm management. A simple record of all sales and purchases showing receipts and expenditures is required and this is kept by the individual farmer for his farm, and is assembled by each farm manager for purposes of analysis of the farming operations. No cost accounting system is undertaken for reasons well known to those who have attempted this work, nor is there any attempt to separate farm projects or enterprises, although this can be done, and is done, to a sufficient degree where such information is desired. Budgeting is followed to the extent of anticipating the extent to which farmers will need assistance in financing their farming operations. Budgets covering all anticipated income and expenditures will be a later development. Such a system of accounts as outlined above serves a number of purposes other than that of testing the profitableness of farm operations as a whole. It reveals the necessity for a diversity of sources of income as well as the necessity of avoiding an increase of indebtedness by "a pay as you go" practice, and reveals and controls excessive expenditures if there is any inclination in that direction. Under more stable prices and with an improved farm programme much light will be thrown on proper land values, in relation to debt adjustments. More emphasis must be placed in the future on valuations in relation to financial returns than on values fixed by a generous loaning policy.

Reports. As a measure of progress on individual farms, comprehensive annual crop reports are required showing acreages, yields, and general improvements along lines of weed control, utilization, and improvement of waste lands, and the progress of the farmer and farming programme. A consolidation of such reports from all farms from year to year shows certain trends and gives a good idea of just what progress is being made. To the individual farmer, it reveals just how he is standing in comparison to his neighbors and the effect of new practices which he is carrying out in his farming operations.

Improvement of Crops. While improved soil conditions and crop rotations are effective in improving crops, improved varieties and proper cleaning and treating of seed are basic steps in the improvement of cereal crops. It is found that it is not possible to depend upon adequate cleaning machinery on the individual farm, and that portable outfits are desirable. An adequate number of farms in a limited territory or zone has now made it possible to undertake the establishment of such portable seed cleaning outfits in at least two of the present zones, and later, extension to all territory. Examination

of seed found in many drills reveals the necessity for such action. Elimination of mixtures, the use of clean seed, and the proper treating of seed results in improved grades that pay the cost of farm management many times.

Livestock Improvements. As already stated the farm management programme makes no attempt to create livestock farms except on such farms where particular features demand the development of such an enterprise. Livestock sufficient for profitable and economical grain growing, and for making self contained farms is the programme. Better, rather than more livestock, is the great need on these farms. No attempt except in a very few cases is being made to establish pure bred herds. Commercial livestock is the general aim, well bred and well fed. The basis of livestock improvement after high class sires are provided is an improved farming programme that provides for not only adequate feed supplies, but the right kind of feed supplies. If one-third of the land now in grain were in legumes and grasses for pasture and roughage, the balance of the land would be producing more grain than the whole is at present. The measure of livestock improvement through better breeding and feeding is shown from year to year through the inventory and farm accounts.

Mortgage End of Farm Management. In addition to the qualifications of carrying out the farm management programme proper, the farm manager has many other duties such as the securing of satisfactory tenants, purchasers, and farm operators. The details of leasing, purchasing contracts, security for all kinds of advances made by mortgage companies, and a general knowledge of legal procedure as carried out in the field in relation to loans on lands and chattels, is very essential. Purchasing of equipment of all kinds as well as livestock and assisting in the advantageous sale of tens of thousands of dollars worth of farm products is another responsibility. Knowledge of the proper construction and repair of buildings is required at all times. Thousands of dollars are saved in these items alone. Building plans to meet the farming programme and financial situation of farms, and not the overloading of the capital structure control every policy of this organization in dealing with the building problem.

Because of the desire of the management of the Colonization Finance Corporation to have the heartiest co-operation of the scientific and technical agriculturists of Canada in the carrying out of this programme of farm management, it may not be out of place to give some information regarding the workings of this organization that would not be mentioned in speaking to the average audience. The field staff of the Colonization Finance Corporation is looking to this group of men for the basic information on which any sound farm management programme must rest. Scientific data obtained through experimentation, demonstration, investigation, and research is invaluable for this work.

The plan of operation of the Colonization Finance Corporation is based on the reasons for the establishment of this organization by the nine co-operating companies. Because of the scattered location of the farm securities of the individual company, an intensive service such as described would be impossible even though the present staff of the individual company had been built up for the type of work which is being carried on. The securities of all

companies in a given territory in need of attention are consolidated in what is called a zone and a man qualified for this work is placed in charge, living at the most convenient point within that territory. The whole purpose is to eliminate the waste of time and travel and to devote the maximum of time to farm problems on the farm and to secure men especially qualified for the type of work to be done.

In determining the number of properties which can be serviced, the most important consideration is the nearness of the properties to each other; the larger the field, the less the number of farms. In a reasonably compact zone, some eighty properties can be given satisfactory attention while a much more compact zone may permit of some increase of this number of properties. Time and the mental attitude of the farmer is an important consideration in this kind of work. Reorganization of farming programmes and farm practices must move slowly and surely to be permanent and successful. We believe that a dollar's worth of farm management spread over several years will accomplish far more than if forced into a short period of time.

Another point which is frequently raised is to what extent the companies are willing to finance the farmer under present conditions. As might be expected, farmers too frequently expect relief and improvement in their condition only from this source, or from some source beyond their farm and without their control. Our first great task is to point them to the problems of the farm itself and a better utilization of what is available on the farm. It is a poor plan to get a farmer out of debt by increasing to any great extent his already heavy indebtedness. However, all companies are making additional advances where the farmer is doing his share and showing signs of making reasonable progress in his farming programme. These advances take the direction of purchases of additional equipment, livestock, seed and feed, and repair and construction of buildings. Collections are not pressed beyond the point that would interfere with the efficient operation of the farm.

To those who are inexperienced in this work or uninformed of the values of farm management, the greatest objection that is raised to a programme such as is being carried on by this company is its cost. Under the present schedule of rates, this cost will average per annum less than 20c per acre. This cost is paid entirely by the interested company. However, in certain cases the farmer has agreed to reimburse the company to the extent of 50% of the total cost. This means that the company carries the entire risk; only in cases where the farmer meets his entire indebtedness and no adjustments are necessary will the farmer be required to make up his share of such charge.

Based upon the above charge, the cost of such service over a period of ten years would amount to $2.00 per acre. In but a fraction of that period, improvements in the weed situation, tilth of the soil, and general improvement of the farm by a well directed farm management programme have added more than that value per acre to the farm, not only salable value to the company, but productive value to the farmer. Indeed, I have seen well farmed tenant-operated farms that would sell from ten to twenty dollars more than adjacent lands not so well managed, and this increased value was reflected in the annual returns to an equal degree. Before undertaking this programme the Directors of this organization investigated this matter thoroughly and

they know and are convinced that results are certain, provided the right kind of programme is carried out.

Unfortunately, few financial records of the cost of previous farm operations are available. We have these in one case which is a large project, and it is significant that the savings in operating expenses last year alone, not taking in consideration added income, will pay management fees for many years. Good management counts most in any business and pays for itself many times over. The main thing is that it be good management.

It may be well to discuss briefly the relationship, and also the differences between the work of the farm manager of the Colonization Finance Corporation and that of the agricultural representative. The work of these men is complementary and the work of one does not supplant the work of the other. Personally, I would like to see the work of the county agent or agricultural representative extended to every province and every section of the province in which we are operating or will operate in the future. Such work carried on by the government would create a better setting for the farm management programme of the Colonization Finance Corporation. My experience has been that a certain resistance to new ideas and new methods is broken down by the county agent or agricultural representative.

Because of the different approach to the farm problems to be solved, the technique and programme of the two types of work is vastly different. The farm manager of the Colonization Finance Corporation represents a company whose equity in the farm is very much greater in many cases than the operator's. He has authority if there be need to exercise that authority. He has the financing where it is needed. The farmer and the farm manager are in the closest relationship; one cannot fail and the other succeed. Both sink or swim together. Both must get results and these results must be obtained from the farm. The farm manager makes recurring regular visits dealing with specific farm problems. As one former agricultural representative told me, "I could tell farmers in a general way, methods of handling quack grass. Now I have to go back week after week and follow the process right through the season step after step, under all kinds of conditions." Work of all kinds must be done in the right way and at the right time. Advice must be on concrete cases, not general but definite and applied at once and put to the test. Plans discussed and agreed upon must be carried out. The first and highest degree of co-operation must be secured.

Having had the closest relationship with both types of work for many years and observed the results, it is not critical to say one method is direct and the other indirect. One will get results from the present generation; the other must wait many years for its most fruitful results. Good intentions on the part of a farmer after an interesting farmer's meeting on sweet clover too often stop at that; under the other plan, the seed goes on the farm and in the ground. Finally, as a purely business organization free from certain governmental restrictions, the Colonization Finance Corporation has distinct advantages.

THE ROLE OF VITAMIN D IN THE NUTRITION OF THE PIG

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INTRODUCTION

Observations made on pigs under practical farm conditions during the winter months in Western Canada as well as developments in connection with a programme of "fall pig" feeding experiments commenced at the University of Alberta in 1920, when viewed in the light of the results of the many experiments in mineral feeding reported, led to the conclusion in 1926 that problems centering around the mineral supply, and the vitamin favoring mineral utilization, were of first rank importance among the problems connected with winter pig production in Canada. The disturbance in connection with mineral supply and utilization was most strikingly manifested in a condition of "stiffness" conforming in a general way with the symptoms outlined by Elliott, Crichton and Orr (*1*) as typical of rickets in pigs, namely, lack of lustre of the hair, decreased appetite and slower rate of growth with lethargy and a general stiff and stilted gait.

It was decided to commence a series of experiments having as their primary object a study of the influence of the various forms of irradiation on general growth and mineral metabolism of winter pigs, and comparing the efficiency of the nutritional factor generated in the animal body, as a result of irradiation, with vitamin D fed through the medium of cod liver oil. Experiments with this object in view were conducted at the University of Alberta during the winters of 1926-27, 1927-28, 1928-29, 1929-30 and the work was extended to include a more detailed study at the Rowett Research Institute, Aberdeen, Scotland, during the winter of 1930-31, and at Cambridge University, Cambridge, England, in 1931. These studies included a consideration of the effect of radiant energy on the rate of growth, feed requirements for growth, calcium and phosphorus level of the blood, composition of bone as well as on the cellular and hemoglobin content of the blood. It will be the object of this paper to briefly discuss the results of this series of experiments and to draw certain conclusions therefrom.

RADIANT ENERGY IN RELATION TO NUTRITION

Space will not permit of a discussion of the position of radiant energy in relation to nutrition and to show the relationship between the various forms of irradiation and vitamin D. A discussion of this subject a few years ago would have been inadequate without a complete review of the experimental basis for a belief in the nutritional importance of irradiation and vitamin D, but in view of the vast amount of experimental work which has been conducted in this field and reported in biochemical, physiological, and pathological literature of recent years, it may be taken for granted that all are informed on this phase of the subject. In a previous paper the writer (*2*) drew attention to certain biological effects of radiant energy.

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The Anti-rachitic Factor and the Pig

Experiments dealing with the anti-rachitic factor on growth of swine have been concerned chiefly with a condition of locomotary disturbance, diagnosed clinically as well as pathologically as rickets in certain cases, and in other cases merely as a condition of "stiffness" of a rachitic nature. In view of the confusion of terms used in describing the conditions encountered in these experiments, it seems well to draw attention to the various types of locomotary disturbances to which reference has been made in the literature.

Zilva, Golding and Drummond (*3*) in one of the earlier experiments dealing with the vitamin D requirement of pigs found that eight out of ten pigs which went "off their feet" showed a typical pathological picture of rickets, the remaining two showing a histological condition of osteoporosis only. In this case pigs which "went off their feet" showed a variation in the pathological state. On the other hand, Elliott, Crichton and Orr (*1*) found that pigs deprived of minerals developed a stiff and stilted gait with deformities of the limbs and showed a pathological condition of the rachitic pattern. Maynard, Goldberg and Miller (*4*) in attempting to ascertain the influence of sunlight on the assimilation of calcium refer to the condition of "stiffness" and Bohstedt (*5*) used the terms "stiffness" and "posterior paralysis" in connection with his report of a series of experiments dealing with the mineral and vitamin requirements of pigs. He concludes that the condition of stiffness may be a manifestation of rickets or osteoporosis or both and that many poorly calcified bone tissues show lesions that do not conform to those of rickets or osteoporosis. Davidson (*6*) draws attention to a form of "arthritis" or "cramps" which resulted in pigs being unable to get up and feed normally when a mineral deficient diet was used. A report of a California experiment (*7*) makes use of the term "leg stiffness" in connection with a condition encountered in pigs deprived of sunlight. In a study of locomotary disturbances of pigs in Australia, Sneddon and Carr-Fraser (*8*) outline the symptoms accompanying a condition of ostalgia in non-pregnant pigs, commonly called "bone strain" or "bone soreness", due to diets which were deficient in mineral elements or in which assimilation was inadequate. In connection with their study, many experimental pigs were slaughtered and histological examinations of bones were undertaken. The condition found appeared to be more typical of osteoporsis or osteomalacia than true rickets. Shaw (*9*) in considering the importance of solar radiation in the development of growing pigs makes use of the term "crippling" to describe a condition encountered but also considers rickets present although no histological study is reported. Sheehy and Senior (*10*) describe an interesting chain of symptoms in connection with a condition of "stiffness" and "cramps" encountered in experimental pigs. Difficulty of locomotion was accompanied by bending of the long bones, with some pigs showing lumpy swellings on the legs. The skin became scurfy, in some cases giving the appearance of a dirty oil smear over the surface of the body.

From this review it would appear that the terms "rickets", "off their feet", "stiffness", "posterior paralysis", "arthritis", "cramps", "leg stiff-

ness", "bone strain", "bone soreness" and "crippling" have been used in connection with locomotary abnormalities in pigs resulting from a deficiency of minerals or a lack of the anti-rachitic vitamin. While true rickets have been encountered in certain of the experiments referred to, it would appear that the term when considered in its histological, as well as clinical sense is likely to be too narrow to cover the various abnormal locomotary conditions which may arise in experiments of the nature of those reviewed. For this reason, the general term "stiffness", rather than the more restricted term "rickets", implying well defined histological bone changes, such as described by Hess (*11*), McCollum and Simmonds (*12*) and Hutyra and Marek (*13*) will be used in connection with the experiments reported in this paper.

Experiments Conducted at the University of Alberta

The first two experiments of the series conducted at the University of Alberta were reported in a previous paper (*1*). In this paper only the experiments conducted during the winters of 1927-28, 1928-29 and 1929-30 will be reported. The three experiments were conducted according to a similar plan and the results, therefore, will be presented on the basis of a three year average, rather than individually.

Objects. (1) To determine whether a ration which appeared to be adequate from the standpoint of protein and vitamins, other than vitamin D, though comparatively deficient in calcium, as well as faulty in Ca–P ratio, would give rise to a condition of stiffness in winter pigs.

(2) To ascertain if the addition of calcium, in the form of ground limestone, to the above mentioned ration, without the addition of vitamin D would prevent the condition of stiffness developing.

(3) To study the effect of sunlight and cod liver oil on pigs receiving a ration containing an adequate supply of calcium and phosphorus, and with the ratio of these minerals properly adjusted.

(4) To determine whether pigs could satisfactorily withstand the absence of sunlight during the early portion of the winter when temperatures are most severe and to note the effect of allowing access to sunlight during the latter portion of the winter.

(5) To study the blood level of inorganic phosphorus and the percentage of bone ash in representative pigs developed under the various experimental conditions.

Plan of the Experiments. In order to indicate the plan of the experiments, the groups included are shown as follows:

Lot I.—Basal ration.	Ground Limestone.	Sunlight ad lib.
Lot II.—Basal ration.	Ground Limestone.	No sunlight.
Lot III.—Basal ration.	Ground Limestone.	Sunlight after Feb. 15.
Lot IV.—Basal ration.	Ground Limestone.	Cod liver oil 0.5%.
Lot V.—Basal ration.		

Each group contained 8 pigs. They were housed in a frame building with such a window arrangement that sunlight never entered the building

during the progress of the experiment. Each group occupied a pen 12 x 9 feet in size, and in the groups allowed access to sunlight, outside pens were available.

Ration Fed. The basal ration used in this experiment was constituted as follows:

Cereal portion.	—Ground barley	—	31.7 lbs.
	Ground oats	—	31.7 "
	Shorts	—	31.6 "
Protein Supplement—	Tankage	—	2.5 lbs.
	Linseed oil meal	—	1.25 "
	Alfalfa meal	—	1.25 "

Since this ration with only slight modifications was used in all of the experiments reported, it seems advisable to discuss its general nature in some detail.

According to commonly used feeding standards, this ration provides an adequate supply of nutrients for normal growth in pigs of this age and possesses a nutritive ratio of 1:5.1, sufficiently narrow for pigs of the age and size used. The quality of protein may be considered satisfactory since it provides a variety from both plant and animal sources. With alfalfa meal as a source of vitamin A, and in view of the low requirement of the pig for vitamins B and C, it would appear that the ration provides for vitamin requirements apart from vitamin D. Cereals have been demonstrated to be low in this factor (*14*) and meat meal is apparently deficient as well (*15*). The question of the vitamin D content of alfalfa meal must be considered in view of the work of Hart and his colleagues (*16*) who found that various samples of alfalfa hay had measurable anti-rachitic properties. Bohstedt (*5*) found that the addition of from 5.5% to 8% of alfalfa meal to a basal ration deficient in calcium, prevented the development of stiffness. While it must be recognized that the alfalfa meal used in these experiments provided a quota of vitamin D, the amount available when this supplement comprised 1.25% of the ration must have been exceedingly small.

All groups had access to salt and were supplied with water three times daily. Grain was fed dry from self-feeders.

Daily Intake of Calcium and Phosphorus. A complete analysis was made of the ash of the various components of the ration, so that the daily intake of calcium and phosphorus could be calculated.

The basal ration in these experiments provided a daily intake of approximately 5 grams of calcium per 100 lbs. live weight. The ratio of calcium to phosphorus without the addition of ground limestone was 1: 2.24. The Ca–P ratio in sows milk is 1: 0.56, a ratio which has been shown to be most favorable to the development of normal skeletal structure.

The addition of 2% of ground limestone to this ration provides an ample daily intake of calcium and phosphorus and adjusts the ratio of the two elements to approximately 1: 0.59.

Results of Alberta Experiments

Table 1 shows the average rate of growth and the average feed requirements for growth in the various groups in the three experiments.

TABLE 1.—*Average daily gains and feed requirements (3 experiments).*

	Lot I Sunlight	Lot II No Sunlight	Lot III Sunlight after Feb. 15	Lot IV Cod Liver Oil 5%	Lot V No Limestone No sunlight
No. of pigs in group	23	23	23	23	16
Average initial weight	58.95	59.73	59.27	59.21	59.74
Average final weight	196.71	191.52	198.15	202.93	170.45
Average daily gain	1.16	1.12	1.17	1.25	.80
Average feed requirement (lbs. per 100 lbs. gain in wt.)	473.41	494.63	475.83	469.97	562.77

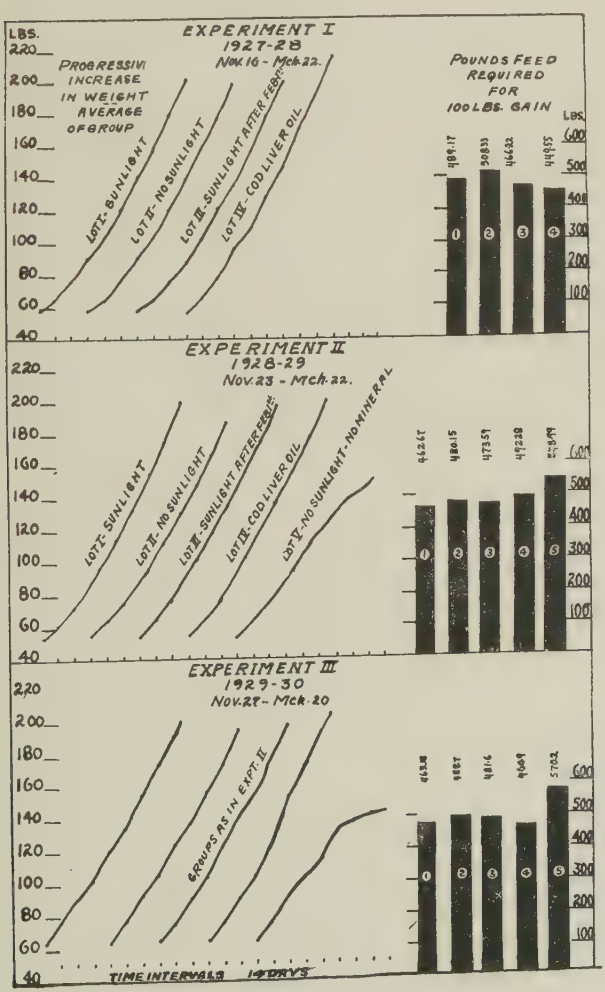
EXPERIMENT I
1927-28
Nov. 16 - Mch. 22.
PROGRESSIVE INCREASE IN WEIGHT AVERAGE OF GROUP
LOT I- SUNLIGHT
LOT II- NO SUNLIGHT
LOT III- SUNLIGHT AFTER FEB. 15
LOT IV- COD LIVER OIL
POUNDS FEED REQUIRED FOR 100 LBS. GAIN
EXPERIMENT II
1928-29
Nov. 23 - Mch. 22.
LOT I- SUNLIGHT
LOT II- NO SUNLIGHT
LOT III- SUNLIGHT AFTER FEB. 15
LOT IV- COD LIVER OIL
LOT V- NO SUNLIGHT - NO MINERAL
EXPERIMENT III
1929-30
Nov. 27 - Mch. 20
GROUPS AS IN EXPT. II
TIME INTERVALS 14 DAYS

Figure 1. Rate of growth and feed requirements. Average of three experiments.

It will be observed that the difference in rate of growth between pigs exposed to sunlight and those not allowed solar radiation is very slight. Being only .04 pounds per day higher on the average in favor of natural irradiation the difference can scarcely be considered significant. In two out of the three experiments, cod liver oil feeding resulted in increased gains and on the average of the three experiments the difference amounts to .13 lbs. daily. The addition of ground limestone in both the experiments resulted in a very significant increase in the rate of growth.

When the feed requirement for Lot II is compared with that of Lots I and III, it will be seen that exposure to sunlight resulted in better utilization of the food consumed. Cod liver oil was efficient in reducing the

feed requirement for growth. The difference in inefficiency of utilization of feed in the cod liver oil groups as compared with the sunlight groups is not greater than could be accounted for on the basis of the additional calorific value of the cod liver oil. The fact that the rate of growth was slightly higher and the feed utilization more efficient when radiant energy was supplied, suggests that while no breakdown occurred in the case of the pigs fed limestone, but deprived of sunlight, the level of physiological activity was somewhat higher in the group supplied additional vitamin D. From the point of view of general appearance of the animals, this was most noticeable in the cod liver oil fed pigs. In these pigs there was a perfect smoothness of skin and gloss of hair, which indicated a high degree of bodily vigor.

The comparative rates of growth in the various groups, as well as the feed requirements for growth, are indicated in Figure 1. Attention is called to the "breakdown" in rate of growth in the pigs in Lot V, when no ground limestone was fed and when the pigs were deprived of sunlight.

The Condition of Stiffness. A basal ration supplying less than 5 grams of calcium daily per 100 pounds live weight and with the Ca–P ratio badly balanced gave rise to a condition of stiffness when pigs were deprived of sunlight. The degree of stiffness varied with the different affected individuals. Stiff pigs tended to knuckle over in the knees with slight enlargement of knees and hocks. The hind limbs were carried somewhat under the body. Some pigs were almost completely paralysed. Not all pigs on the calcium deficient diet developed the locomotary abnormality. The difference in reaction to the ration could not be accounted for by a higher initial weight or slower rate of growth on the part of the pigs which remained normal. It would seem that certain pigs are either able to utilize the available intake of minerals more efficiently by virtue of more complete absorption or greater cellular activity, or they enter the winter with a greater storage of vitamin D.

Analysis of blood for inorganic phosphorus failed to yield any very significant results. The condition of stiffness did not appear to be accompanied by any noticeable difference in the level of inorganic phosphorus as compared with other groups in the experiments where pigs developed normally. The rather small number of samples studied, together with the fact that the level of blood calcium was not determined, makes it rather difficult to draw any definite deductions from this phase of the series of experiments.

Analyses of fat free femurs of representative litter mate pigs in the various groups in the three experiments indicated that vitamin D did not exert any influence on bone development under the conditions of these trials. The percentage of ash in the bones of pigs from the various groups is shown in Table 2.

TABLE 2.—*Percentage ash in bones.*

	% Ash in bones
Lot I.—Sunlight	61.93
Lot II.—No sunlight	60.73
Lot III.—Sunlight after Feb. 15	62.01
Lot IV.—Cod liver oil .5%	60.76
Lot V.—No limestone. No sunlight	56.80

The only group of pigs showing an ash content of bone which might be considered bordering on subnormality is the group deprived of additional calcium and not allowed access to sunlight. The main factor in promoting bone development and avoiding stiffness was the addition of calcium, in the form of ground limestone, to the ration. It would appear that the ample supply of calcium and the favorable Ca–P ratio which obtained in the group fed cod liver oil or exposed to sunlight, prevented the vitamin D factor from exerting the influence which it might have under more unfavorable conditions of mineral supply.

The influence of radiant energy under conditions of low calcium intake was not studied in these experiments but it was in connection with the experiments to be reported in the next section of this paper.

Experiments at Rowett Research Institute

The next experiment of the series reported herein was conducted at the Rowett Research Institute at Aberdeen, Scotland, where the writer was graciously provided with animals, assistance, and facilities for the conduct of further research on the problem.

This experiment was outlined in such a way that results could be compared with those secured in the Alberta experiments and in addition further experimental lots were included so that artificial irradiation could be compared with solar radiation and the various forms of radiant energy compared under conditions of high and low calcium intake.

The basal ration was kept the same in this experiment as in previous trials, in order that any abnormal conditions which might develop in the pigs in the various groups could be related to those appearing in the experiments already reported. This arrangement made provision for a comparison of the reaction of the experimental animals to rations similar in composition, but grown in countries where growing and harvesting conditions vary markedly.

Objects of the Experiment. The objects of this experiment may be briefly stated as follows:

(1) To compare sunlight, artificial irradiation and cod liver oil as sources of vitamin D when superimposed upon (a) a ration low in calcium but adequate in nutrients, minerals other than calcium, and vitamins other than vitamin D, and (b) a ration containing an ample supply of calcium and other minerals as well as adequate nutrients and essential vitamins other than vitamin D.

(2) To study the hematopoietic influence of solar and artificial irradiation in winter grown pigs.

Consideration was given to the latter problem as a result of a common belief, that under conditions of close confinement, winter pigs are likely to suffer from anaemia in addition to conditions of a rachitic nature. The results of this phase of the experiment will not be reported at this time but will form the basis for a paper to be published at a later date.

Methods of the Experiment. In this experiment eight groups of seven pigs were used. The various groups in the experiment, from the point of view of ration and experimental treatment were arranged as follows:

Lot	I.—Basal ration.	No minerals.	
Lot	II.—Basal ration.	No minerals.	Sunlight.
Lot	III.—Basal ration.	No minerals.	Artificial irradiation.
Lot	IV.—Basal ration.	No minerals.	Cod liver oil 1%.
Lot	V.—Basal ration.	Minerals.	
Lot	VI.—Basal ration.	Minerals.	Sunlight.
Lot	VII.—Basal ration.	Minerals.	Artificial irradiation.
Lot	VIII.—Basal ration.	Minerals.	Cod liver oil 1%.

As has been mentioned, the basal ration used was the same as in the experiments reported previously. Analysis of the various feeds showed a slightly higher calcium content in some so that only 1.5 lbs. of ground limestone (97.07% $CaCO_3$) was added to 100 pounds of the basal ration in order to properly adjust the Ca-P ratio.

In order to make provision for a liberal supply of mineral matter in the "mineral" groups, and in order that the experimental animals might respond to their appetites in this regard, they were allowed free access to common salt, ground limestone, steamed bone flour and ferric oxide. Cod liver oil was fed to the groups receiving this source of vitamin D at the rate of 1% of the grain ration and was thoroughly mixed with the dry grain. The vitamin content of the cod liver oil was not assayed. The grain was fed dry from self-feeders. Water was kept before the pigs at all times.

Systems of Irradiating Animals. The two groups of pigs which were allowed access to sunlight were driven from their pens daily unless weather conditions were unfavorable, and were confined to outside paved pens favorably situated with regard to exposure to sunlight. Records were kept of the actual hours of exposure. Studies of the ultra-violet content of sunlight at Aberdeen showed that while it was small during the fall and early winter months as compared with summer intensity, still it was present in measurable quantities.

The pigs that were exposed to artificial irradiation were driven daily to a pen in an adjoining building and were confined to a pen 7 by 3½ feet in size for purposes of exposure to a quartz mercury-vapor lamp. (British Hanovia Quartz Lamp Co.) The daily exposure of the pigs to the lamp was started at two minutes and increased by two minutes daily until the animals were under the lamp for thirty minutes by the end of the second week. Later the length of the exposure was increased to 40 minutes. The average distance from the lamp to the pigs' backs was 3 feet.

A photograph of the spectrum of the lamp being used was obtained by means of a Hilger E.1 spectograph with the lamp at a distance of 3 feet. This photograph showed a well marked band in the region of a wave length of 2,800 Angstrom units, indicating that the lamp was emitting rays of a wave length which is most effective in the process of forming vitamin D from ergosterol.

Methods Employed in Blood Analysis. Calcium was estimated on blood serum according to the method of Kramer and Tisdall. Inorganic phosphorus was estimated on whole blood according to Havard and Reay's modification of Brigg's modification of the Bell-Doisey method.

While all the pigs were on the basal ration and were being treated similarly with respect to feeding and management methods, they were bled

from the tail and were subjected to a preliminary bleeding before being alloted into groups. They were bled at intervals of from three to four weeks during the progress of the trial and altogether the blood of each pig was sampled on five different occasions. Data were secured which might be considered representative of the five months during which the experiment was in progress, namely December to April, inclusive.

Results of Rowett Experiment

The results of this experiment will be interpreted on the basis of the relation of the various forms of radiant energy to, (a) rate of growth (b) the development of a condition of stiffness and (c) the calcium and phosphorus content of the blood.

Rate of Growth. Space will not permit of detailed discussion of the rate of growth in this trial. Figure 2 will suggest the trend in the various lots. A study of this chart will suggest that exposure of pigs to sunlight and the quartz mercury-vapor lamp, as well as the administration of cod liver oil assisted in promoting growth under conditions of both low and high calcium intake.

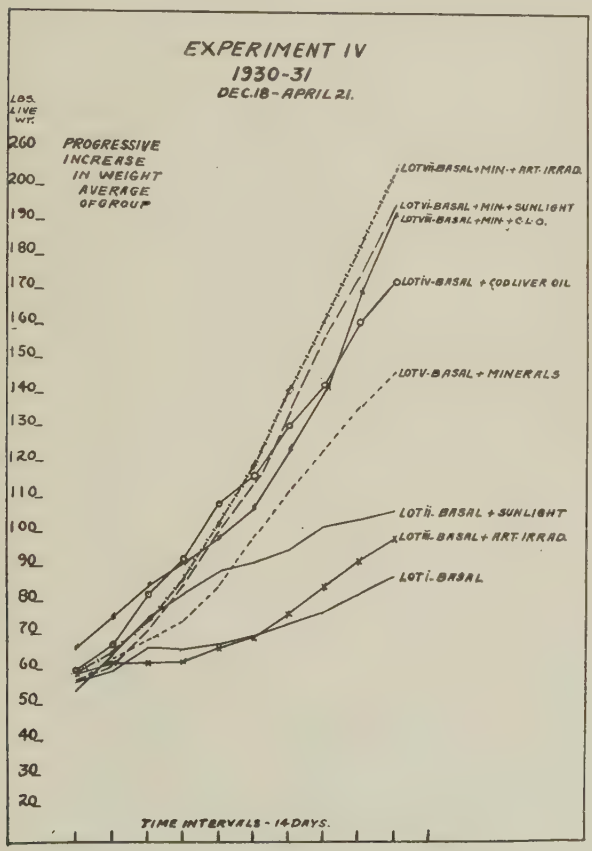

Figure 2. Rate of growth. Experiment IV (Rowett Institute).

When the basal ration was deficient in calcium, cod liver oil proved more effective in this regard, but when the ration was adequate in Ca, the irradiated pigs made more rapid growth.

The addition of ground limestone to the basal diet appeared to be an important factor in improving the growth of the pigs.

The Condition of Stiffness. In this experiment cases of stiffness developed in three groups of pigs, namely Lot I, basal; Lot II, basal and sunlight; and Lot V, basal and minerals. The condition was similar in general symptoms with that which developed in the Alberta experiments although in the present cases there was more evidence of malnutrition and lack of thrift as indicated by coarse hair and an oily, dirty appearance of the skin.

Two cases of "stiffness" occured in Lot I (basal), death following in one instance from symptoms suggestive of tetany.

Four cases occurred in Lot II (basal and sunlight) and these were the most marked of those occurring in the experiment. The more rapid rate of growth in this group (see Figure 2) as compared with Lot I may account for the general occurrence of the condition in this lot. Since stiffness occurred in this group exposed to sunlight, and did not occur in the group irradiated by the mercury-vapor lamp or fed cod liver oil, it may be assumed that the winter sunlight available during the progress of the trial did not supply sufficient radiant energy to compensate for the lack of calcium in the basal diet, whereas the mercury vapor-lamp and the cod liver oil did. The reason for this will become apparent when the level of calcium and phosphorus in the blood is discussed.

A result which was not in harmony with the developments in the Alberta experiments was the occurrence of three cases of stiffness in Lot V where ground limestone was added to the basal ration. In the first three experiments reported no clinical symptoms suggestive of abnormal bone development occurred when the basal ration was fortified by the addition of ground limestone and the Ca-P was properly adjusted. In this trial the addition of ground limestone as a source of calcium was not sufficient to obviate the difficulty. It is suggested that the slight difference in the vitamin D content of the feeds used in the basal ration may have accounted for the inconsistency. Cereals and alfalfa hay grown under different conditions with respect to exposure to sunlight, may vary sufficiently in vitamin D content to account for the breakdown in this group.

Sunlight appeared to correct the condition which developed in Lot V. The fact that no cases of stiffness occurred in the "limestone"—"sunlight" group indicated that while the sunlight failed to prevent the condition in Lot II, it possessed anti-rachitic properties and further indicated the lower vitamin D requirement when calcium was supplied in sufficient volume and when the Ca-P ratio was favorable.

Results similar to those obtained by exposure to sunlight were secured by artificial irradiation and the feeding of cod liver oil.

The distribution of the cases of stiffness in this experiment indicated that the condition, appearing clinically, rachitic in nature, was due to a combination of low calcium and a deficiency of the vitamin D factor.

The Calcium and Inorganic Content of the Blood. In this experiment the calcium and inorganic phosphorus content of the blood were both determined in order that changes in the level of both elements could be studied.

In order to arrive at a "normal" figure for the commencement of the experiment, 100 pigs including those used in the experiment were sampled and the calcium and inorganic phosphorus content of the blood determined.

The mean values for calcium and inorganic phosphorus of the blood of 100 pigs, together with the standard deviation and co-efficient of variability of these values are as follows:

	Mean Value	Standard Deviation	Co-efficient of Variability
Calcium	11.85	0.963	8.13
Inorganic Phosphorus	8.09	1.599	19.76

Figure 3 shows the average calcium and inorganic phosphorus content of the blood serum of pigs in the various groups in the experiment expressed in milligrams per 100 ccs. of serum. The figures are presented by months, as the blood of all pigs was actually sampled once during each of the months indicated and this arrangement suggests the trend in the calcium and inorganic phosphorus level of the blood during the progress of the experiment.

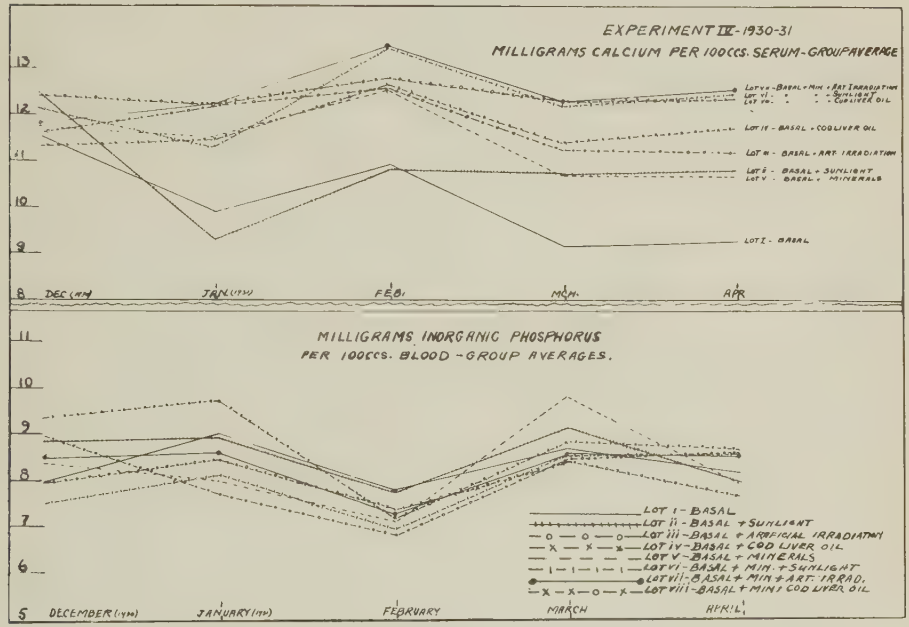
EXPERIMENT IV-1930-31
MILLIGRAMS CALCIUM PER 100CCS. SERUM-GROUP AVERAGE
LOT I - BASAL
LOT III - BASAL + ARTIFICIAL IRRADIATION
LOT IV - BASAL + COD LIVER OIL
LOT II - BASAL + SUNLIGHT
LOT V - BASAL + MINERALS
DECEMBER JANUARY FEBRUARY MARCH APRIL
MILLIGRAMS INORGANIC PHOSPHORUS
PER 100CCS. BLOOD - GROUP AVERAGES.
LOT I - BASAL
LOT II - BASAL + SUNLIGHT
LOT III - BASAL + ARTIFICIAL IRRADIATION
LOT IV - BASAL + COD LIVER OIL
LOT V - BASAL + MINERALS
LOT VI - BASAL + MIN. + SUNLIGHT
LOT VII - BASAL + MIN. + ART. IRRAD.
LOT VIII - BASAL + MIN. + COD LIVER OIL
DECEMBER JANUARY FEBRUARY MARCH APRIL

Figure 3. Level of calcium and inorganic phosphorus in the blood during the months of December—April inclusive. Experiment IV (Rowett Institute).

It is to be noted that the two groups of pigs which developed the most severe cases of stiffness showed a reduction in blood calcium during the first month, a condition which was maintained during the progress of the trial. It is noteworthy here that in Lot II (basal-sunlight) as compared with Lot I (basal), while the condition of stiffness was maintained until the close of the experiment, the calcium content of the blood under the influence of sunlight was brought up to 10.9 mgms. per 100 ccs. of serum as compared with 9.30 in the group deprived of radiant energy. It would appear that the sunlight, while not sufficiently potent in ultra-violet rays to synthesize an adequate supply of vitamin D, under the conditions of low calcium intake, did assist in the retention of additional calcium.

The rather even level of blood calcium in the basal groups, irradiated artificially and fed cod liver oil was in keeping with the lack of clinical symptoms of bone abnormality.

The drop in blood calcium in Lot V (basal and ground limestone) was of special interest since it follows so closely the development of the locomotary disturbance. The condition of crippling which occurred in these pigs, whether of a rachitic nature or otherwise, seemed to be definitely associated with low blood calcium.

Exposure of pigs in Lot VI to sunshine resulted in maintaining the calcium of the blood at a significantly higher level, a situation which was accompanied by a more favorable rate of growth and freedom from external manifestations of bone abnormality. This result was secured in a similar way by irradiation with the quartz mercury-vapor lamp and by feeding cod liver oil.

A result which appears worthy of special mention was the higher level of blood calcium in the groups fed the ground limestone. In every instance where comparable pens are considered (I and V, etc.) it will be seen that the blood calcium is higher throughout the experiment. It is apparent that the higher daily intake of calcium due to ground limestone feeding is reflected in the higher level of calcium in the blood.

In this experiment the inorganic phosphorus content of the blood never dropped to a particularly low level although a general drop occurred in all groups during the month of February, at which time the calcium rose to a relatively higher level than at other periods of the experiment. This occurrence may be due to a seasonal factor and is of interest in view of the fact that the majority of cases of stiffness in winter pigs develop during the month of February. There did not appear to be any more marked drop in blood phosphorus in the groups where stiffness developed than in other groups.

A study of the trends as shown in Figure 3 will indicate that as the level of blood calcium is increased or decreased from month to month, the inorganic phosphorus is decreased or increased accordingly. The tendency appears to be, as far as possible for the regulating mechanism to maintain an even concentration as expressed by the product of the two elements. The occurrence in this experiment with regard to the reciprocal action on the part of the Ca and P is in keeping with the results secured by Auchinachie (*17*) with sheep, Hall and King (*18*) and Wilgur (*19*) with chicks and Kramer and Howland (*20*) and Park, Guy and Powers (*21*) with humans.

Experiment at Cambridge University

The fifth experiment of the series was conducted in the Department of Animal Nutrition, School of Agriculture, Cambridge University, Cambridge, England, where animals and facilities were generously placed at the disposal of the writer. The period of the experiment was from June 2 to September 10, 1931.

It was thought that there would be an advantage in repeating the programme under different environmental conditions and with solar radiation of summer intensity. Accordingly the experiment was repeated at Cambridge.

In objects and methods, the fifth experiment constituted a duplicate of the experiment just reported so that it will not be necessary to go into detail regarding the plan of the experiment. In view of the fact that facilities for artificial irradiation were not available, only six groups of pigs were included in the trial and these were arranged as follows:

Lot I.—Basal. No irradiation.
Lot. II.—Basal. Minerals. No irradiation.
Lot III.—Basal. Cod liver oil (10ccs. per head daily).
Lot IV.—Basal. Minerals. Cod liver oil (as above).
Lot V.—Basal. Sunshine.
Lot VI.—Basal. Minerals. Sunshine.

In this experiment the pigs used were of a higher initial weight than those used in previous trials. They were farrowed in February and averaged 84.6 lbs. in weight at the commencement of the experiment.

The same basal ration was used as in previous experiments. On account of the higher calcium content of the basal ration in this experiment, especially in the meat meal fraction, the daily intake per 100 lbs. live weight was slightly higher and the ratio of phosphorus to calcium was lower. Taking into consideration the calcium content of the water supplied, the pigs on the basal group in this trial would ingest a total of 6.39 grams of calcium and the Ca-P ratio would be adjusted to 1.0:1.37.

Results of Cambridge Experiment

The following table shows the rate of increase in live weight during the progress of the experiment:

Table 3.—*Rate of growth, experiment V, June 2 to Sept. 10, 1931.*

Lot	Av. Initial Wt. (lbs.)	Av. Final Wt. (lbs.)	Av. Daily Gain (lbs.)
I.—Basal	84.1	233.3	1.49
II.—Basal and minerals	85.4	240.8	1.55
III.—Basal and cod liver oil	84.9	238.5	1.53
IV.—Basal and minerals and cod liver oil	83.6	244.5	1.61
V.—Basal and sunlight	83.7	232.2	1.48
VI.—Basal and minerals and sunlight	85.8	239.8	1.52

It will be noted from Table 3 that all pigs in this experiment made satisfactory growth and the general rate of growth was more active than in previous experiments. The average daily gain of 1.49 pounds in the group being fed the basal ration indicates that the daily intake of minerals was sufficient for satisfactory growth. The addition of minerals made for only slight improvement in the rate of increase in live weight.

The difference as compared with previous trials may be accounted for on the basis of the higher initial weight of the pigs in this experiment, and the slightly higher daily intake of calcium. A combination of these conditions

in this experiment undoubtedly lessened the requirement of vitamin D from the growth standpoint. Access to sunlight during their early history may have provided for a sufficient storage of the anti-rachitic factor to permit of normal growth under the conditions of the higher daily calcium intake and a more favorable Ca-P ratio.

In previous experiments failure to grow and general evidence of malnutrition on the part of the pigs restricted to the basal diet was accompanied by marked clinical symptoms of disordered bone metabolism. In this experiment, the pigs in Lot I not only made very remarkable growth, but no condition of stiffness developed.

Calcium and Phosphorus Content of the Blood. The blood of pigs was sampled for calcium and inorganic phosphorus as in the previous experiment, and four samples were secured in all from each pig. The results expressed in group averages for the months of May, June, July and August are shown in Figure 4.

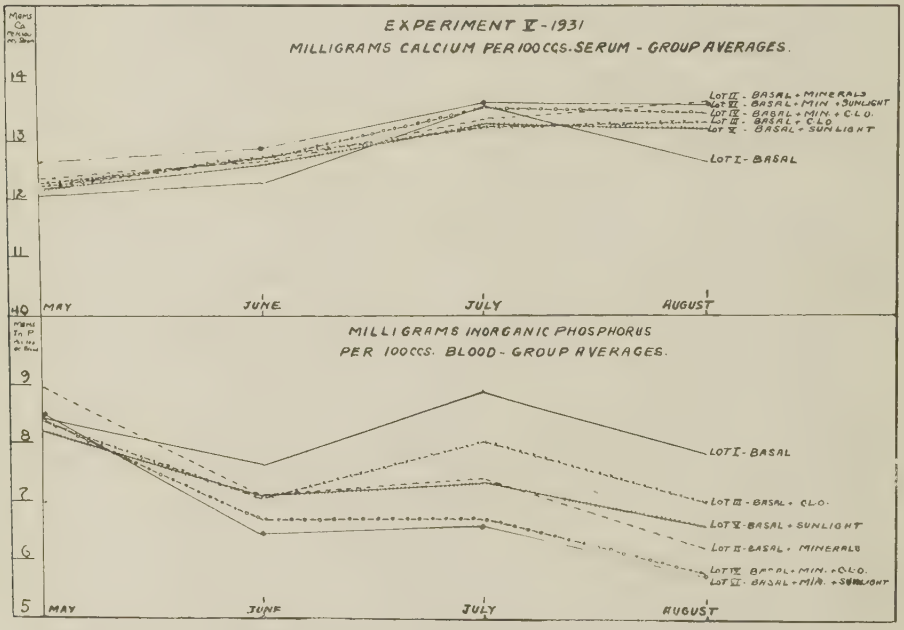

Figure 4. Level of calcium and inorganic phosphorus in the blood during the months of May—August inclusive. Experiment V (Cambridge University).

The results of the preliminary bleeding on the 36 pigs used in this experiment indicated the following with regard to mean values for calcium and inorganic phosphorus.

	Mean Value	Standard Deviation	Co-efficient of Variability
Calcium	12.29	0.418	3.4
Inorganic Phosphorus	8.45	0.88	10.41

These figures compare with 11.85 for calcium and 8.09 for inorganic phosphorus as mean values on samples of blood from 100 pigs bled prior to the commencement of Experiment IV.

In this experiment the influence of the radiant energy factor on the calcium and phosphorus level of the blood is not as marked as in the previous experiment, but the principles observed there are again in evidence here. Reference to the chart will show that the calcium level of the blood is lowest in the basal ration, while in Lot III (cod liver oil) and Lot V (sunlight) the level is noticeably higher than the mean value at the beginning of the trial. It will also be observed that the groups fed minerals in addition to the basal diet show a slightly higher content of blood calcium than those fed the basal diet only. This is in agreement with the results found in the previous trial.

The higher level of phosphorus in the basal groups, at the close of the trial, is similar to the occurrence in the previous experiment and is in line with the general evidence as to the reciprocal action on the part of the calcium and inorganic phosphorus in the blood. The initial rise in calcium in June was accompanied by a drop in phosphorus.

Summary and Conclusions

A series of five experiments has been reported. In connection with these trials the various forms of radiant energy were compared with respect to their influence on the rate of growth, level of calcium and phosphorus in the blood, and bone metabolism in the pig.

The following conclusions may be drawn from the results of the experiments reviewed:

1. Exposure to solar or artificial irradiation as well as cod liver oil feeding promoted growth in the pig, the response being inversely proportional to the calcium content of the basal ration.

2. A condition of stiffness, clinically suggestive of rickets, was prevented or ameliorated by the introduction of the radiant energy factor.

3. The addition of calcium to a basal ration in the form of ground limestone was an important factor in preventing the development of stiffness in pigs, in promoting growth, and in lowering the feed requirement for growth.

4. The feeding of ground limestone resulted in an increase in the ash content of the bone.

5. The rachitic syndrome which developed was characterized by a diminution in the level of calcium in the blood without any consistent change in the organic phosphorus.

6. Pigs fed ground limestone in addition to the basal ration showed a higher content of serum calcium than those confined to the basal diet.

7. The reciprocal action on the part of the calcium and inorganic phosphorus on the blood is demonstrated in the pig.

8. The anti-rachitic factor, whether ingested in the medium of cod liver oil, or synthesized in the body as a result of exposure to sunlight or the quartz mercury-vapor lamp, exerted an influence in raising the calcium level of the blood, thereby increasing the calcium-phosphorus product.

ACKNOWLEDGEMENTS

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I also wish to acknowledge my indebtedness to the Canadian Society of Technical Agriculturists for the award of the $1,200 T. Eaton Scholarship in 1930, which assisted very materially in enabling me to prosecute a portion of the work reported in this paper at the Rowett Research Institute, Aberdeen, Scotland, and at Cambridge University, Cambridge, England.

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SOME OBSERVATIONS ON THE VARIABILITY OF THE AMOUNT AND COMPOSITION OF THE ASH OF THE WAGENER APPLE UNDER NOVA SCOTIAN CONDITIONS[1]

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In recent years there has been considerable discussion in horticultural circles concerning the effect on the keeping quality of the fruit in storage of continued fertilization of apple orchards with nitrogenous fertilizers alone, and in particular with nitrate of soda. In this connection it has been reported (*2*, *11*) that fruit possessing a high nitrogen content is peculiarly liable to early breakdown in store, and (*5*, *10*) that apples possessing a high content of potassium, and possibly of phosphorus also, store better than fruit low in these constituents. The validity of the claim that nitrogen content is thus related to spoilage in store has been vigorously contested by Gourley (*8*, *9*), Degman (*7*) and others. The reported effects of potassium and phosphorus in this connection appear to have been less thoroughly investigated although Weinberger (*13*), for example, denies that potash fertilization improves storage quality. Further, a search of the literature indicates the available data respecting the variability with climatic, soil and cultural conditions of the amount and composition of the mineral constituents of the apple to be very limited. The most notable work in this field which has come to the writer's attention is that of Brown (*3*, *4*, *5*). In view of the desirability of the accumulation of additional information in this connection the series of analyses herein reported was commenced in 1928.

Materials Used

With the co-operation of Mr. R. D. L. Bligh, Assistant Horticulturist, samples of fruit of the Wagener variety were obtained from the fertilizer plots at the Dominion Experimental Farm, Kentville, N.S. These plots were set aside for the purpose of conducting fertilizer trials when the land was cleared in 1912 and have since been subjected to controlled fertilization. The soil is a sandy loam with a sandy to gravelly sub-soil. Clean cultivation is maintained until about the end of June when a cover crop is sown. Records have been kept of the amounts of fertilizer applied and the yields of fruit obtained, and these have in recent years been supplemented by tests of the keeping quality of the fruit in ordinary cool storage. It may be remarked at this point that these tests have shown no significant differences in the keeping quality of the apples which may be attributed to the application of the various fertilizers used, notwithstanding the fact, which will appear subsequently in this report, that considerable differences have been found in the mineral composition of the fruit. For the purposes of the present study representative samples of the fruit, usually consisting of 30 apples each, were supplied from plots fertilized respectively with nitrate of soda, muriate of potash, acid phosphate, basic slag and limestone, and from those receiving no fertilizer whatever since the trees were set out. Exceptions in

[1] Paper read before the Horticultural Group of the C.S.T.A. during the 12th Annual Convention at the Manitoba Agricultural College, Winnipeg, June 15th, 1932.

[2] Associate Professor of Chemistry.

the size of sample used were as follows: in 1929 only 12 apples were available from the limestone plot, while in the same year the non-fertilized plot sample consisted of 28 apples only, 4 being taken from each of 7 replicate plots; in 1930 and 1931 the size of the non-fertilized sample was 40 apples, 5 being taken from each of 8 replicate plots in each of these years. In 1931 no fruit was obtainable from the limestone plot.

Methods of Analysis

The seeds and stems were removed from the fruit, which was then finely sliced and dried at 96°C. The dried residue was ashed, small portions at a time, in Sillimanite dishes placed on wire gauzes over the heating coils of an electrical Kjeldahl digestion shelf, the heat being carefully regulated so as to avoid losses by volatilization. The hot ash was finally rapidly transferred to tared weighing bottles with ground glass stoppers. The alkalinity of the ash was determined by dissolving a suitable amount (about 2 gms.) of the ash in a measured excess of standard HCl solution, which was then neutralized with standard NaOH solution using methyl red as indicator. The results are expressed as the number of milliliters of 0.1 N HCl solution required to neutralize the alkalinity of one gram of the ash. The solutions thus obtained were then acidified by addition of 5 ml. of concentrated nitric acid, heated to the boiling point, cooled, transferred to volumetric flasks and made up to volume. The major ash constituents, potassium, phosphorus, calcium and magnesium were determined on suitable aliquots. The gravimetric sodium cobalti-nitrite method was used in the determination of potassium, the Pemberton method (*1*) for phosphorus, and calcium and magnesium were determined in accordance with the method outlined by Daughters (*6*).

Experimental Results

The 3-year averages of the results obtained in the analysis of fruit of the crops of 1928-1930 inclusive are given in Table 1, in which are shown the amounts of the various constituents expressed as per cent of the ash. There are also included in this table the *maximum percentage variations* in these constituents found by, (a) the writer for the Wagener variety under the influence of the various fertilizer treatments described, (b) Brown (*5*) for the Bramley's Seedling variety as influenced by soils of varying fertility, and (c) reported by Ingle (*12*) for the varieties Koo, Northern Spy, Versfeld and Lord Wolseley as indicating differences in the composition of the ash of these varieties. These percentage variations are calculated on the lowest values in Tables 1, 2 and 3.

Examination of these analytical results shows that for three of the six fertilizer treatments, viz., acid phosphate, basic slag, and no fertilizer, the total amounts of ash and the percentage composition of the ash are quite similar. That is, if the results for the fruit from the check plots be considered as *normal*, the application of neither acid phosphate nor basic slag produced very great variations in the quantity or composition of the inorganic constituents of the fruit. On the other hand, the exclusive use of nitrate of soda, muriate of potash or limestone does appear to result in important modifications of the mineral composition of the apple under the conditions obtaining in

TABLE 1.—*Ash constituents expressed as per cent of ash in 1928, 1929 and 1930 crops.*

Treatment	Per cent ash in F.W.	Alkalinity	Phosphoric Anhydride	Potash	Lime	Magnesia
			(Expressed as per cent of ash)			
Nitrate of soda (150 lbs. per acre)	0.156	136	10.21	54.6	4.91	4.54
Muriate of potash (150 lbs. per acre)	0.248	143	6.59	57.1	3.24	4.08
Acid phosphate (350 lbs. per acre)	0.184	137	10.81	57.2	3.94	3.84
Basic slag (500 lbs. per acre)	0.175	137	11.05	55.4	4.03	4.76
No fertilizer	0.192	137	10.39	55.6	3.75	4.30
Limestone (2 tons per acre)	0.158	132	12.44	54.5	4.50	4.38
Maximum Percentage variation:						
DeLong	59	...	89	5	52	24
Brown	43	...	84	21	95	79
Ingle	20	...	50	12	45	..

this test. Thus, the fruit from the nitrate of soda and limestone plots is decidedly lower in total ash content and there is a higher proportion of lime in the ash than in the fruit from the check plots. Further, in the case of the limestone plot the proportion of phosphoric anhydride in the ash is also notably high. The muriate of potash plot shows the most striking deviations from the *normal* however. The fruit from this area has shown the highest total ash content in each of four years, the ash has consistently been very low in phosphoric anhydride, and the percentage of lime in the ash is also below that for any other plot.

The interpretation of these results is, of course, a matter of some complexity. The following suggestions appear reasonable to the writer, however. The low ash content of the nitrogen-fertilized fruit may be attributed to competition between the vegetative and reproductive organs under (a) the stimulating effect of this element upon the former and (b) the limited supplying power of a soil of this type for the chief ash constituents potash and phosphoric anhydride. Further, since limestone favours nitrification processes and the growth and decay of cover crops, a similar explanation may perhaps apply in case of the low ash content of the fruit from this plot also, in addition to which the well known depressant effect of applications of lime upon the availability of potash (the major constituent of the ash) no doubt plays a role in this connection. On the other hand, the high total ash in case of fertilization with muriate of potash may be considered to be the result of the recognized ability of plants to absorb amounts of potassium in excess of their needs when it is available.

In Table 2 the analytical results calculated as percentages of the fresh weight of the fruit are presented. This mode of representation is probably of greater biochemical and physiological significance than that adopted in Table 1.

On the basis of the percentage of the individual ash constituents found in the fresh weight of the fruit it will be noted that the nitrogen-fertilized fruit has the lowest amounts of phosphorus and potassium. This is in line with the facts of low soil level and lack of supply of these elements in the form of fertilizers. Applications of muriate of potash are again clearly indicated to have an effect in increasing the amount of potassium in the

TABLE 2.—*Ash constituents expressed as per cent of fresh fruit in 1928, 1929 and 1930 crops.*

Treatment	Phosphoric Anhydride	Potash	Lime	Magnesia
	(Expressed as per cent of fresh weight)			
Nitrate of soda	0.0159	0.0852	0.0077	0.0071
Muriate of potash	0.0163	0.1416	0.0080	0.0101
Acid phosphate	0.0199	0.1052	0.0073	0.0071
Basic slag	0.0193	0.0970	0.0071	0.0083
No fertilizer	0.0200	0.1068	0.0072	0.0083
Limestone	0.0197	0.0861	0.0071	0.0069
Maximum percentage variation:				
DeLong	26	66	13	46
Brown	43	41	54	33
Ingle	60	34	68	..

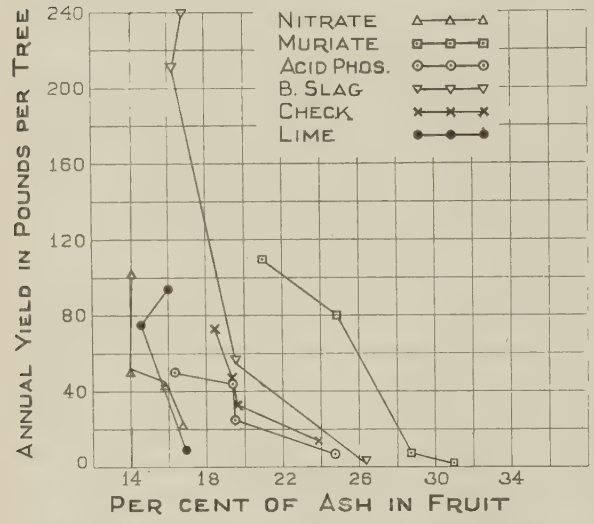

Figure 1. Per cent of total ash in relation to annual yield of fruit per tree.

fruit. On the other hand, the abnormally high proportion of phosphorus in the ash of the fruit from the limestone plot is now seen to represent a practically *normal* fruit content of this element, when calculated on the fresh weight basis. The amount of potash in the fruit from this plot is, however, decidedly low, which is in accord with the accepted opinion that the application of calcium compounds depresses the availability of the soil potassium. As before, the fruit from the acid phosphate, basic slag and no fertilizer plots shows a marked uniformity of composition when contrasted with that from the plots just mentioned. It is the opinion of the writer that these larger variations from the *normal* exhibited in the composition of the fruit from the latter series of plots and discussed above are validly attributable to the use of the respective fertilizer treatments. In this connection, a particularly convincing picture with relation to the situation in respect of total ash is presented when the percentage of ash is plotted against the annual yield of fruit per tree, as in Figure 1, in which the results for the four years 1928-1931 inclusive are presented.

This figure indicates the consistency with which low results for the amounts of ash in fruit from the nitrogen- and limestone-fertilized plots and high results in that from the potash-fertilized plot have been obtained. It also clearly indicates the total ash content of the fruit to be dependent upon the amount of crop borne by the tree. This possibility seems to have been

insufficiently emphasized in the previous work on the mineral composition of the apple. For example, Brown (*5, p. 817*) makes the unequivocal statement that seasonal differences are "not nearly so great as those caused by variations in the soil", and, although she states that 1926 was a "bad year" gives no specific data respecting the actual effect upon yield of fruit. The writer cannot agree that Brown's experimental data are completely in accord with the above-quoted statement, since calculations from the results reported give the values shown in Table 3. The *seasonal* and fertilization differences found in the present study are also included for comparison.

TABLE 3.—*Maximum soil and seasonal differences expressed on the fresh weight basis.*

	Total ash	Potash	Phosphoric Anhydride	Lime	Magnesia
Data by Brown (1925 and 1926):					
Per cent variation with soil composition (10 soils)	32	29	41	56	48
Per cent variation with soil type (8 loams; 2 sands)	8.5	3.5	5	20	8.5
Per cent variation with season (6 soils)	12	22	37	47	30
Data by DeLong (1928, 1929 and 1930):					
Per cent variation with soil fertilization (6 fertilizers)	68	78	43	28	58
Per cent variation with season	37	67	41	79	46

Consideration of the extreme variations from season to season as expressed in the above table shows that these may actually equal or be greater than the extreme variations from soil to soil. However, this is not to imply that Brown's conclusions respecting the effect of soil composition upon the mineral content of the fruit are invalid. On the contrary, of the ten soils studied by this investigator, the five highest in "available" potash and phosphoric acid content produced, in each of the two years, the fruit highest in these constituents in four cases out of five, which may fairly be considered good evidence for the existence of a correlation between the availability of these mineral nutrients and the inorganic composition of the fruit. The results herewith presented afford additional support to such a conclusion.

Nevertheless, the term *seasonal variation* as used by Brown is not definitely stated to exclude the influence of yield variations, and, as used by the writer hitherto in this paper does include wide fluctuations of the latter nature. The question thus arises, how much of the *seasonal variation* may be attributed to the effect of crop yield? Brown (*5*) attributes the seasonal differences observed in the years 1925 and 1926 to the difference in rainfall in the months April-June in the two seasons. Fortunately, very considerable precipitation variations during the growing season have also been observed in the present study, and of four crop years covered by it, two may be characterized as *dry* and two as *wet*. The data are given in Table 4.

TABLE 4.—*Effect of precipitation on ash content.*

Year	Inches of rain April-June	Inches of rain May-July	Inches of rain May-Oct.	Average per cent of total ash	Average yield in pounds of fruit
Data by Brown:					
1925	5.03			.183	
1926	6.13			.1835	
1925	5.64			.1915	
1926	6.75			.196	
Data by DeLong:					
1928		8.36	14.26	.174	161
1929		10.42	19.60	.197	72
1930		7.03	13.35	.185	158
1931		9.31	19.82	.240	28

It is unfortunate that, in the case of the present study, the *wet* seasons are also the low crop seasons. Hence it is as yet impossible to arrive at a definite conclusion concerning the respective effects of these two influences upon the ash content of the fruit. However, examination of the data so far obtained supports the opinion that the crop yield effect is predominant. Thus, the average total ash content of the fruit from all the plots in 1929 is found to be considerably smaller than in 1931, and, whereas the rainfall in these seasons was practically the same, the average crop was much smaller in the latter year. It is to be hoped that as the work progresses information may be accumulated which will permit of a more definite decision on this point, especially as such information would appear to be of possible value in connection with such problems as the relations of light crops to physiological breakdown, or of moisture supply to the incidence of bitter-pit.

SUMMARY

The results of a 3-year study of the mineral composition of the Wagener apple indicate that the total ash content and the proportions of the major ash constituents may be influenced by the application of certain fertilizers in commercial quantities. Thus, the continued use of nitrate of soda alone results in a decidedly low total ash content of the fruit as compared with that from near-by trees receiving no fertilizer. The amounts of the principal ash constituents potassium and phosphorus are also notably below those found in unfertilized fruit. Parallel effects in respect of total ash and potassium content are found to follow the use of limestone only. On the other hand, repeated applications of muriate of potash alone result in a marked increase in the total ash and potassium content of the fruit. The effects following the use of acid phosphate and basic slag are much less pronounced, perhaps the most notable being a slight apparent increase in the percentage of phosphorus in the ash.

Seasonal variations in the amount of ash present in the fruit are large. These seasonal effects seem to be related most closely to the size of the crop, but climatic factors, particularly rainfall during the growing season, may also be involved.

Conclusions respecting the correlation of mineral composition and storage quality in the fruit of the apple depend upon so many considerations,

and the existing evidence in this connection is so contradictory, that no definite pronouncement appears to be justified. In the present instance the results are negative.

Acknowledgments

The author wishes to express much appreciation of the co-operative spirit of the officers at the Dominion Experimental Farm, Kentville, N.S., and especially of his indebtedness to Mr. R. D. L. Bligh, Assistant Horticulturist, without whose aid these results could not have been obtained. Acknowledgment is also made of the accurate and efficient analytical assistance rendered by Mr. E. L. Outhouse, B.Sc.

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PSEUDO-BLACK CHAFF OF REWARD WHEAT[1]

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It has been observed that the glumes of Reward wheat may often be discolored in a manner, which, upon superficial examination, resembles the black chaff disease caused by *Bacterium translucens undulosum* described by Smith (*1*). Cases occur where it may be difficult for some to distinguish with certainty whether this discoloration is black chaff or not.

In the fall of 1929, a particularly severe case of this type of discoloration was observed on the plots of Reward wheat at the Provincial School of Agriculture at Claresholm, Alberta, and it has been found each year since in Alberta as well as in Saskatchewan. Similar cases have been observed elsewhere in Alberta (*2*, *3*). In 1931 at the Dominion Experimental Station, Scott, Saskatchewan, pseudo-black chaff was found in varying intensities on all seven selections of Reward grown in the nursery. It was also found on Marquis.

A fairly accurate picture of the type of discoloration referred to is shown in Plate I, a, b, and c. The plants may be numerous, occasional, very rare, or apparently absent, depending upon the field examined. As a rule, all the spikes of each plant are affected. Samples of normal and pseudo-black chaff plants were brought to the laboratory for further examination.

It was found that these discolored areas were not swarming with bacteria as would be the case with typical black chaff, although several kinds of bacteria and some fungi, including species of *Cladosporium*, *Alternaria* and *Macrosporium* were isolated. It was apparent that the discolored areas did not always occur in longitudinal, parallel, more or less shrunken stripes, as is characteristic of the black chaff disease. Furthermore, the discoloration rarely extended to the peduncle of the inflorescence, as is the case of black chaff, but was confined almost entirely to the glumes, and the rachis, especially to those parts which were exposed to the light (see Plate 1, c). The kernels were not discolored, nor did they appear to be more shrunken than the normal grain.

These observations suggested that while the discoloration might be due to some organism, systemic or non-systemic, it might also be a physiological disease due to the expression under certain environmental conditions of

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[2] Plant Pathologist and formerly Assistant Plant Pathologist, respectively.

Plate I. Pseudo-black chaff on Reward wheat. (See opposite page).

a. Left, normal Reward Spike, Edmonton. X 0.75. Right, pseudo-black chaff on Reward spike, Claresholm. X 0.75.

b. Close-up view of pseudo-black chaff on Reward spike. X 2.

c. Top, grain and glumes of normal black pigmented Kahla. X 2.
Bottom, grain and glumes of pseudo-black chaff Reward. X 2.

d. Unstained cross-section of normal Reward glume. X 85: g, X 350.

e. Unstained cross-section of pseudo-black chaff Reward glume. X 85: h, X 350.

f. Unstained cross-section of normal black pigmented Kahla glume. X 85: i, X 350.

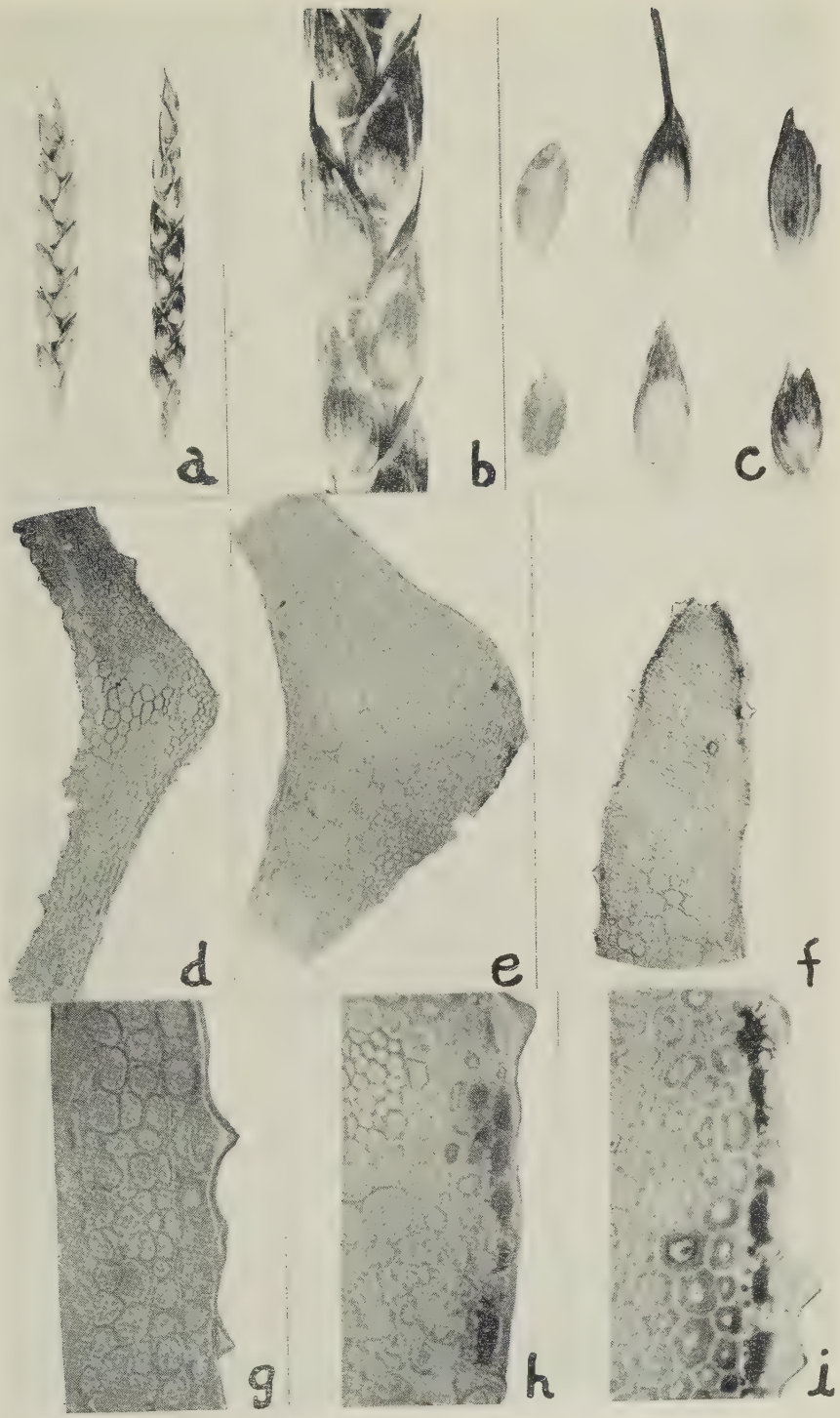

Plate I. See foot of opposite page for explanation.

some hereditary color factor which was still present in the genotype of the Reward variety. Accordingly a few tests were made to investigate these possibilities.

A test was made to determine if the discoloration might be due to a systemic parasite. On December 18 and January 3 seed from pseudo-black chaff plants was given the hot-water treatment as generally recommended for the control of loose smut of wheat. Non-treated seed was also planted for the purposes of comparison. The glumes and rachis of all plants from the treated and non-treated seed alike were characteristically discolored. However, from a similar planting as above, made August 25, neither the glumes nor rachis were discolored on any of the plants. In 1931 monthly plantings were made of Reward from seed which showed the discoloration, as well as from seed which did not show it. As before, half of the seed of each lot was given the hot-water treatment just prior to planting. It was found that the discoloration definitely occured in plants from both the treated and the non-treated seed which showed the discoloration, and also very faintly in the plants from seed which did not show it previously. The intensity of the discoloration varied with the time of planting. However, the discoloration, when it occurred, was usually greater on the spikes of plants from seed which had previously shown the discoloration. It was also found that this type of discoloration fades out if the plants are allowed to stand in the pots on the benches for some time after ripening.

Another test was made in which the bacteria and fungi isolated from the discolored glumes from the field were tested in one series by being applied as inoculum at seed level, and in another series as a bacterial and spore suspension to the glumes, being incubated for two days in the usual manner. The seed for these tests was from Reward produced from plants which were known to be free from discoloration and from black chaff. It was surface disinfected in a 1-1000 mercuric chloride solution for five minutes and was sown in August. This test failed to produce the typical discoloration on either rachis or the glumes in both series.

A histological examination was made of the glumes of normal and of discolored Reward and Marquis wheat, and the normal black pigmented glumes of Kahla. Unstained and stained paraffin sections were prepared of this material. The external gross appearance of the glumes of normal and discolored Reward wheat, as well as the normal black pigmented glumes of Kahla are illustrated in Plate I, a, b, and c, respectively. It will be observed that the general appearance of the discolored regions in the glumes of Reward is very similar to that of the normal black pigmented region in the Kahla variety. In both cases, it was observed that the pigment occurred in the cavity of the cells and also that fine darkened connections extended from cell to cell through the pits (see Plate I, e, f, h, and i). The discoloration in Reward, and the normal pigment in Kahla, was usually in the epidermal cells only, although in some instances it extended to a depth of several cells. In all cases the tissue of discolored Reward was intact, and apparently free from fungal threads or bacterial invasion.

To briefly summarize the results obtained from both cultural and histological studies, it appears that the best explanation for the discolored

glumes often found on Reward wheat, and sometimes on Marquis, is that some strains of Reward still carry color factors, which, under suitable light intensity, produce the dark pigmented areas mentioned. If this is the case, then many strains of Reward wheat which now produce dark glumes will continue to do so, the intensity of which will depend upon certain environmental factors, principally light.

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CURRENT PUBLICATIONS

INHERITANCE OF BUNT AND LOOSE SMUT REACTION AND OF CERTAIN OTHER CHARACTERS IN KOTA × RED BOBS AND GARNET CROSSES. Thomas Kilduff, formerly Assistant in Genetics and Plant Breeding, University of Alberta. Contribution from the Department of Field Crops, University of Alberta, Edmonton, with financial assistance from the National Research Council of Canada. Canadian Journal of Research *8*:2; 147-172. February 1933.

Genetic studies were made in F_2, F_3 and F_4 on the progeny of two common wheat crosses, Kota × Red Bobs and Kota × Garnet. Two Chlamydospore collections from pure line hosts were used for inoculation in the bunt studies. The heritable nature of bunt reaction was clearly demonstrated in these crosses and evidence obtained that the degree of resistance found in Garnet must be conditioned by a single major factor. No genic hypothesis could be offered to explain the findings in regard to loose smut reaction due to a lack of agreement in infection percentages in the F_3 and F_4. Red kernel color in Kota and Red Bobs was found to be governed by two factor pairs. The results on the inheritance of awn characters agreed with the earlier findings of Clark and other workers with crosses of similar awned types, several factor pairs being invloved. Two main factors appeared to condition the difference in strength of straw between Kota and Garnet, but the entire expression of the character can best be explained on a multiple factor basis. Correlated inheritance studies, made with the use of the correlation ratio η, indicated the presence of two linkage groups concerned with reaction to the bunt forms used. However, the linkage apparent between strength of straw and bunt susceptibility factors and between awn type and bunt resistance factors is not considered to be close enough to interfere with breeding for desirable bunt resistant varieties.

METHODS OF INOCULATION OF WHEAT WITH *HELMINTHOSPORIUM SATIVUM* P.K. AND B.[1]

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INTRODUCTION

The fungus *Helminthosporium sativum* P.K. and B., a cause of disease in cereal crops in Western Canada, is being recognized more and more as a factor of major importance in the farming industry. It is particularly destructive as a cause of foot rot in wheat, barley and rye, and as such must be investigated with a view to developing measures of control suitable to common farm practices. Such investigations have been started during the past few years. In order to carry on the work further it was felt that the methods of producing infections of the host plants at will should be reviewed and methods developed by which uniformity of results might be obtained. This is especially necessary for example in the comparison of relative resistance or susceptibility of varieties to the various forms of disease produced by *H. sativum*. The object of the work here reported is to make some contribution to the knowledge of the common methods of inoculation which may be used in studies of *H. sativum* and other similar pathogens.

LITERATURE REVIEW

Few comparative studies appear to have been made on methods of inoculation with *H. sativum* on cereals. G. A. Scott (*15*) reports a comparison of five methods of distributing solid inoculum of *H. sativum* in pots for greenhouse infection studies. Simmonds (*18*) made a comparative test of some methods of inoculation in pots in the greenhouse using *Fusarium culmorum* (W. G. Sm.) Sacc.

Methods which have been used to introduce *H. sativum* into the soil may be classified as follows:

(*a*) Addition to the soil of a solid medium overgrown with the fungus. Cooked or autoclaved wheat has been used by Dosdall (*4*), Christensen (*1*), Henry (*9*) and Greaney and Bailey (*6*). McKinney and Davis (*13*) considered this medium toxic to wheat plants and used a mixture of equal parts of barley and oats for culturing *Ophiobolus graminis* Sacc. Other solid media that have been used include wheat and barley mixtures (*7*); wheat and oat mixtures (*2*); oats (*4*); oat meal (*1*); oat hulls (*15*, *16*, *17*, *18*, *19*, *20*, *21*); rice (*22*); and diseased plant parts (*1*).

(*b*) Applications of spore suspensions to the soil were made by Dosdall (*4*) and McKinney (*12*).

(*c*) Stakman (*22*) and McKinney (*12*) applied spore suspensions of *H. sativum* to the seed, which was sown while still wet.

(*d*) Simmonds (*18*) dried spore suspensions on the seed before sowing.

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[1] Paper read before the Canadian Phytopathological Society, Guelph, Ontario, June 1931. Contribution from the Division of Botany, Experimental Farms Branch, Dominion Department of Agriculture, Ottawa, Canada.

[2] Assistant Plant Pathologist.

[3] The writer wishes gratefully to acknowledge the helpful suggestions of Dr. P. M. Simmonds throughout the investigation.

(*e*) Greaney and Bailey (*6*), Christensen (*1*), and Hayes *et al* (*8*) made use of naturally infested soil in greenhouse and field experiments.

(*f*) Stakman (*22*), and Christensen (*1*) report obtaining disease with *H. sativum* by using naturally infested seed.

(*g*) Recently Henry (*10*) has used sterilized soil as a culture medium for inoculation work with *H. sativum.*

(*h*) Fuchs (*5*) reports inoculation of barley seed with conidial suspensions of *Helminthosporium gramineum* Rab. under vacuum, followed by culturing for two days and drying.

From among the solid media, the oat-hull mash was selected for special attention since it has been much used in this laboratory. Studies were made on the effect of age of inoculum, the amount and method of application of inoculum, and the influence of sterile medium on the young seedlings. The spore suspension method of inoculating mature seed, especially where the conidia are dried on the grains, received consideration. In connection with this phase of the study the effect of a period of incubation of the conidia before drying arose. The inoculation of immature grain to establish the fungus parasitically before the seed is ripe was tried as a method.

Methods and Materials

Most of the work reported in this paper was done with a culture of *H. sativum* isolated from a discolored grain of Kubanka wheat at Saskatoon in 1922. This culture has been used in inoculation work for several years and is known to be definitely pathogenic on common varieties of wheat, barley and rye. Where a solid medium was employed for the production of inoculum a commercial product, known as "Vim" and sold as a stock food, was used. This consists chiefly of finely-ground oat hulls with a small portion of meal added. When prepared as a mash and sterilized this provides an excellent medium for the development of *H. sativum.* The inoculum thus produced is easily broken up and handled. For the purpose of inoculating by a spore-suspension method the fungus was grown for ten days or two weeks on potato dextrose agar in tubes or in petri dishes. The suspensions were strained through a fine-mesh wire screen to remove bits of agar and masses of mycelium. The seed to be treated was weighed out and one half the weight of spore suspension was added, and the whole shaken together. The seed was soaked for twenty minutes and the excess of suspension drained off. Unless otherwise stated the seed was immediately placed in a desiccator.

The seed, variety Marquis, selection Ottawa 15, was grown at Indian Head, Saskatchewan in 1929. It was tested for germination and freedom from disease-producing fungi. Six hundred grains sown in sterile sand gave a germination of 98%. Two seedlings were blighted and one other was lesioned. As the seed was so nearly free from disease-producing fungi no surface sterilizations were made in any of the work.

The soil was a black clay loam mixed with coarse, screened sand in the proportion of five to one by volume. Unless otherwise stated the soil was not sterilized. Checks were always sown to give an indication of the amount of disease arising from the soil and seed. In most of the experiments six-inch pots were used, while in one test crocks of one-gallon capacity were employed as soil moisture can be maintained more nearly constant in them.

Greenhouse pot experiments were, in most cases, harvested two weeks after the date of sowing. Counts were taken on the number of seedlings produced and the number which were distinctly blighted. The seedlings which remained were divided into three classes: (*a*) those with no lesions on the coleoptiles; (*b*) those with slight lesions; and (*c*) those with severe coleoptile lesions. Numerical ratings were calculated from the data obtained in this manner using the formula employed by Simmonds (*18*). Values of four, three, two and one were given respectively for non-emergence, seedling blight, severe coleoptile lesions and slight coleoptile lesions.

THE SOLID MEDIUM METHOD OF INOCULATION

Age of inoculum. The oat-hull method of inoculation is an example of the use of a solid medium which is added with the fungus to the soil to be inoculated. Since variations in the amount of disease secured in the greenhouse with this method are frequently rather large, especially where young and old inocula are used, tests were performed in which inocula of various ages were compared.

H. sativum was grown on oat-hull mash and sterilized in Erlenmeyer flasks of 200 cc. capacity. Such preparations were made at irregular intervals the cultures being grown and stored in a basement where the temperature of 21° to 22°C. was fairly uniform and where light was excluded. Pot tests were sown from time to time using in each experiment a number of cultures of varying ages. In every case 10 grams of inoculum were added to each pot at seed level. The inoculated and check pots were always in quadruplicate and the average results taken. The results are summarized in Table 1 in which only infection ratings are given.

TABLE 1.—*The influence of age of H. sativum cultures upon the degree of infection produced in wheat seedlings in the greenhouse. The soil was not sterilized and no sterile medium or inoculum was added to the checks.*

Test No. 1 Jan. 4, 1930		Test No. 2 Feb. 13, 1930		Test No. 3 March 27, 1930		Test No. 4 Dec. 10, 1930		Test No. 5 Dec. 24, 1930	
Age of inoculum days	Infection rating %	Age of inoculum days	Infection rating %	Age of inoculum days	Infection rating %	Age of inoculum days	Infection rating %	Age of inoculum days	Infection rating %
check	6.1	check	14.7	check	3.0	check	3.0	check	1.5
9	95.9	7	98.9	7	91.4	14	93.5	6	99.2
17	90.4	13	88.2	16	86.1	39	74.9	12	99.0
50	48.2	21	85.9	56	43.4	50	68.2	28	97.2
72	36.1	49	61.4	154	32.5	77	31.5	53	59.8
252	29.7	57	50.9	....	....	153	21.7	91	76.3
....	....	80	49.6	....	....	195	29.0	166	39.0
....	....	112	22.2	....	....	....	....	....	....

From Table 1 it is apparent that there is a profound effect produced on the infection by differences in age of inoculum. Young cultures produced a high degree of infection which fell rapidly as the age of the cultures increased up to approximately one hundred days. Beyond this point an increase in age of culture does not result in further marked reduction of infection. The variable results are due in part to seasonal variations of light and temperature but probably the greatest factor was soil moisture, which is not readily controlled in ordinary pot experiments.

A field test, using cultures of *H. sativum* grown on oat-hull medium for periods up to 102 days, was made at Indian Head. Seedling data included non-emergence and seedling blight counts while the weight of grain per row was taken at harvest time. The rows were 18.5 feet in length and one foot apart with 200 seeds per row. The rows were replicated three times giving a total of 800 seeds for each age of inoculum respectively.

TABLE 2.—*Summary of a field test to determine the effect of age of H. sativum cultures grown on oat-hull medium as a method of inoculation of wheat. The total possible emergence in each case was 800. The reduction in stand was calculated on the check as 100% and was based on non-emergence and seedling blight.*

Age of Inoculum days	Emergence No.	Seedling blight No.	Yield of grain grams	Weight per measured bushel lbs.	Reduction in	
					Stand %	Yield %
Check	776	2	1,117	50.4	0	0
102	574	30	611	47.4	29.7	45.3
61	589	45	627	47.5	29.7	43.9
39	499	53	561	46.5	42.3	49.8
16	162	36	222	43.0	83.7	80.1
7	121	29	161	43.0	88.1	85.6

It will be noticed from Table 2 that the reduction in yield follows the same general trend as the reduction in stand of plants. Where the reduction in stand was greatest with the young inoculum, the surviving plants had a much larger feeding area per plant and although their efficiency was probably reduced due to lesioning of the root and crown regions, they produced more seed per plant than the checks. Where the reduction in stand was only 29 to 30% of the plants the reduction in yield was 44 to 45%. This can be explained by assuming an impaired efficiency of the plants due to lesioning of the underground parts.

A greenhouse test was outlined by which it was hoped to show whether the old oat-hull inoculum was less potent in producing disease due to the presence of staling products or whether the differences were due to deterioration or loss of vigour of the conidia in the old cultures.

Two cultures of *H. sativum* were selected which had been grown on oat-hull medium in Erlenmeyer flasks of 200 c.c. capacity for 16 and 116 days respectively. A portion of each culture was used in making up spore suspensions. The spores in each case were washed five times in sterile distilled water by centrifuging, pouring off the supernatant fluid, and resuspending the spores in water each time. The suspensions, of approximately equal spore concentration, were used in inoculating two twenty-gram lots of wheat seed. Portions were sown while still wet. The remainders were placed in desiccators to dry. Second and third seedings were made from each lot of seed after three and eleven-day periods respectively. Checks consisting of untreated seed were sown at the same time as the first group. Also portions of the original oat-hull cultures were used in inoculating additional groups of pots. The seedlings were harvested two weeks after sowing and counts made on emergence, seedling blight and basal lesions. Table 3 is a summary of the results.

TABLE 3.—*The effect of washing conidia to free them from possible staling products in an effort to account for old inoculum being less aggressive on wheat than young inoculum.*

Age of inoculum	Method of inoculation	Period of desiccation days	Infection rating %
Check			3.1
116 days	Oat hull		3.4
	Spore suspension	0 (sown wet)	3.7
	" "	3	35.5
	" "	11	29.1
16 days	Oat hull		97.5
	Spore suspension	0 (sown wet)	70.2
	" "	3	97.9
	" "	11	99.2

The attempt to free the conidia of the old culture from possible staling products did not result in an increased amount of disease. Thus there appeared to be no water-soluble toxic substance to account for the lack of aggressiveness in the old culture.

Experiments on the addition of sterilized media or sterilized inoculum to the check pots in greenhouse work. A preliminary test gave evidence of reduced emergence of seedlings in pots where sterile medium (ground oat hulls) was added at seed level, as compared with pots in which nothing was added. A small test was outlined to confirm this observation. Groups of four pots each were treated in the following manners: (*a*) checks without the addition of oat-hull medium or inoculum; (*b*) inoculated with a six-day-old culture; (*c*) inoculated with a culture one hundred and six days old; (*d*) treated with an autoclaved six-day-old culture; and (*e*) treated with an autoclaved culture one hundred and six days old. Data were taken at the end of two weeks and infection ratings calculated. In the cases where autoclaved inoculum was added the infection ratings are due almost entirely to non-emergence, there being little more lesioning than in the checks. Isolations from seedlings which failed to emerge did not yield a fungus which might have been the cause. The infection data are given in Table 4.

TABLE 4.—*The effect of autoclaved cultures of H. sativum on wheat seedlings as compared with inoculations and untreated checks. The cultures used were of two ages, 6 and 106 days respectively. The dry weight was taken on the tops and roots of all plants which emerged from 200 seeds sown for each treatment.*

Age of culture days	Treatment	Infection rating %	Dry weight grams
	Check—not inoculated	4.1	6.06
6	Inoculated	97.5	0.27
6	Inoculum autoclaved	77.1	1.05
106	Inoculated	72.1	1.48
106	Inoculum autoclaved	43.6	3.03

In both the old and the young cultures the autoclaved portions gave quite high disease ratings almost comparable with those produced by the inoculum in each case. A second experiment was designed to indicate

whether the injury done to the wheat seedlings by the autoclaved cultures was due to some foreign substance of a toxic nature in the oat-hull medium. For this purpose other media were used and the amount per pot reduced in part of the experiment. The media used were: (*a*) coarse oat hulls, not ground or prepared in any way; (*b*) a mixture of equal quantities of barley and oat grain; and (c) the usual ground oat-hull mixture, "Vim". Several flasks of each medium were prepared and autoclaved. These were divided into three groups, one of which was not inoculated. The other two groups were inoculated with *H. sativum*. After a period of two weeks one of these groups was sterilized by autoclaving for twenty minutes at fifteen pounds pressure. The inocula, media and autoclaved inocula prepared in this way were used in sowing a series of 48 pots. In addition 4 pots were sown without treatment as checks. The infection ratings, taken two weeks later, are given in Table 5.

TABLE 5.—*The effect of sterile media and autoclaved inocula compared with living inocula and untreated checks upon wheat seedlings. The media are: (a) coarse oat hulls; (b) a mixture of equal parts of barley and oat grain; (c) "Vim", 10 grams per pot; and (d) "Vim", 2 grams per pot.*

Medium	Treatment	Infection rating %
Check		2.7
Coarse oat hull	inoculum	92.6
	autoclaved inoculum	76.5
	sterile medium	59.2
Barley oat mixture	inoculum	87.5
	autoclaved inoculum	83.6
	sterile medium	59.5
Ground oat hull 10 grams per pot	inoculum	97.4
	autoclaved inoculum	91.4
	sterile medium	69.6
Ground oat hull 2 grams per pot	inoculum	93.7
	autoclaved inoculum	85.1
	sterile medium	74.6

There are not significant differences between the three kinds of media used in the test to indicate that one possesses a greater degree of toxicity than another. Further evidence against a theory of a toxic action is found in the fact that two grams of medium produced as much injury as did ten grams.

A second possible theory of the injury produced by the medium or autoclaved inoculum on germinating wheat is that these substances are excellent media for the rapid development of soil fungi and bacteria. The use of unsterilized soil in the two experiments just reported gave point to this view. An experiment was outlined in which parallel series were run in autoclaved and unsterilized soil. To make the test as uniform as possible one-gallon crocks were used and the moisture maintained at 60% of the moisture holding capacity of the soil. Ten grams of inoculum, medium and autoclaved inoculum respectively were placed at seed level. Untreated crocks served

as checks. Table 6 gives the infection ratings obtained at the end of two weeks, and Figure 1 shows representative crocks.

TABLE 6.—*The effects of sterile medium and autoclaved inoculum on wheat seedlings in sterilized soil as compared with unsterilized soil. The infection ratings are based upon a total of one hundred seeds which were sown in two crocks for each treatment.*

Treatment	Infection ratings	
	Soil sterilized %	Soil unsterilized %
Check	7.0	2.5
Sterilized medium	7.2	53.5
Inoculated	80.0	81.0
Autoclaved inoculum	10.7	88.0

Figure 1. The front row of crocks contains unsterilized soil while the rear series contains soil which was autoclaved at fifteen pounds pressure for two hours. Crocks 9 and 42 are checks; 36 and 30 were treated with 10 grams each of sterile oat-hull medium at seed level; 31 and 44 were inoculated with *H. sativum;* and 39 and 46 were treated similarly with an autoclaved culture of *H. sativum* on oat hulls. Fifty seeds were sown to each pot.

It is evident from these data that if the soil is sterilized no serious injury is caused to the wheat seedlings by the addition of sterile media or autoclaved inoculum as occurs where unsterilized soil is used. It appears probable that the injury in the latter instance is due to the growth of soil inhabiting organisms upon the sterile material placed at seed level. A common soil fungus *Rhizopus nigricans* was used to inoculate three flasks containing respectively *H. sativum* on oat-hull medium, an autoclaved culture, and sterile medium. No growth of the contaminant occurred on the living culture of *H. sativum*. It grew quite well on the autoclaved culture but not quite so rapidly as on

the sterile oat-hull medium. A similar reaction probably occurs when these materials are placed in soil which has not been sterilized.

As pointed out in connection with Table 4 there is no distinct type of lesion present on the seedlings which are distorted and fail to emerge. Thus active parasitism does not appear to take place. The manner in which the injury is produced is not apparent. Two possibilities arise: first, that one or more of the soil organisms developing on the favourable media around the germinating seed may produce poisonous substances which inhibit normal development; and second, that the soil organisms, growing vigorously on the media may attack the endosperm and use up the food reserves essential to the normal development of the embryo. Hurd (*11*) has described a reaction of the latter type in germinating wheat produced by the saprophytes, *Rhizopus nigricans* and *Penicillium* spp. where the seed coats have been broken.

THE SPORE SUSPENSION METHOD OF INOCULATING WHEAT SEED WITH H. SATIVUM

The suspension method of inoculation has been used in both greenhouse and field experimentation. Usually the seed is dipped in a conidial suspension at the time of sowing, or the suspension is poured over the seed in the pot or trench before it is covered with soil. Simmonds (*18*) dipped oat seed in conidial suspensions of *Fusarium culmorum* and dried them rapidly. The advantage of this method, he points out, lies in the possibility of using a seed drill by means of which extensive field tests might be carried on.

An experiment was designed to determine what influence drying might have upon the resultant amount of disease produced. A quantity of wheat seed was inoculated with a fairly heavy spore suspension of *H. sativum*, and a similar quantity was treated with sterile water in the same manner to serve as checks. Two hundred seeds of each were sown while wet in six-inch pots, the remainders being placed in desiccators to dry. A second seeding was made after twenty-four hours and a third after three days. On the fourth day, when the seed was quite hard and dry, it was removed to bottles which were tightly corked. Further seedings of 200 kernel lots were made 10, 24, 52,

TABLE 7.—*The influence of drying a spore suspension of H. sativum on wheat seed and storing on the relative amount of disease produced. Seedings were made from time to time during the process of drying and storage. Only the infection ratings are given.*

Elapsed time between treatment and sowing days	Infection ratings			
	First series		Second series	
	Check %	Inoculated %	Check %	Inoculated %
0 (sown wet)	2.5	32.1	5.4	55.6
1	3.7	70.4	5.4	67.4
3	7.2	69.4	4.2	70.9
10	6.2	94.4	5.4	70.6
24	1.6	84.0	8.9	50.4
52	11.4	66.1	13.1	52.6
80	5.4	88.0	24.0	49.6
108	12.4	62.9	20.7	40.0
136	7.2	56.0	....	....

80, 108 and 136 days after the time of inoculation. About one month later a duplicate series was begun using a newly inoculated quantity of seed. Each group of pots was harvested two weeks after the date of seeding and data taken on the emergence, seedling blight and basal lesions. The infection ratings obtained are given in Table 7.

Considerable irregularity is to be expected between the results due to lack of uniformity of the greenhouse conditions throughout the duration of the experiments. There is, nevertheless, evident in the results of the inoculated series an increase in the disease ratings co-incident with desiccation up to a period of about ten days. Longer periods resulted in a rather rapid decrease in the infection ratings followed by a more gradual decrease.

A test was conducted in the field in 1930 similar to those just reported but with one important difference. The seed was treated on different days, desiccated, and stored until seeding time, then all sown on the same date. Seeding was done on May 22 so that the soil temperatures would be sufficiently high to favour infection. A series of rod rows, one foot apart, in the order shown in Table 8 with two buffer rows at each end, was replicated three times. Since each row contained two hundred seeds there were eight hundred sown to each treatment. Data consisted of the number of seedlings which had emerged three weeks after seeding and of the blighted seedlings. From these counts the reduction of stand of plants due to inoculation was computed using the stand of the respective check as one hundred per cent. At harvest time the yield of grain per row in grams was obtained and the reduction due to inoculation calculated in percentage using the respective checks as standards. A summary of the results appears in Table 8.

TABLE 8.—*Results of a field test on the effect of drying a suspension of H. sativum conida on wheat seed for various periods of time compared to sowing the grain wet.*

Elapsed time between treatment and sowing days	Treatment	Emergence No.	Seedling blight No.	Yield grams	Reduction in	
					Stand %	Yield %
0	Check	763	1	749		
	Inoculated	664	29	519	16.6	30.7
3	Check	773	3	851		
	Inoculated	511	36	426	33.1	49.9
10	Check	757	0	876		
	Inoculated	487	29	418	39.5	52.3
25	Check	759	1	766		
	Inoculated	559	36	468	31.0	38.9
36	Check	764	3	810		
	Inoculated	656	26	527	17.2	34.9

From these results it is readily seen that there is a marked increase in the amount of disease produced by drying the suspension on the seed for periods up to ten days. Thereafter a decrease is evident. These facts correspond to the results of the greenhouse test of similar nature shown in Table 7. From the tenth day on there was a negative correlation between the amount of the disease and the period of storage.

In seeking to account for the increase of the disease rating up to the tenth day, apparently due to drying the spore suspension on the seed, the most

likely explanation appeared to be that before drying was complete a period of incubation intervened. This was quite possible since a fairly large quantity of seed had been placed in the desiccators at one time. A greenhouse experiment was outlined to check up this possibility. A quantity of seed was inoculated with a spore suspension of *H. sativum*. This was divided into five equal parts one of which was placed immediately into a desiccator to dry. The remaining four parts were covered in petri dishes and placed in an incubator at about 24.5°C. They were uncovered and removed to the desiccator at the completion of the following intervals: 3, 18, 27 and 45 hours respectively. A parallel series was treated similarly with sterile water in place of a spore suspension to serve as controls. In the last lot of seed a number of kernels had begun to sprout, while in the lot of seed incubated for 27 hours the grains had begun to swell. After being dried in the desiccator the several portions of seed were sown on the same date in pots. Notes were made after a period of two weeks on emergence, seedling blight and basal lesioning, and disease ratings calculated. Table 9 is a summary of the results.

TABLE 9.—*The effect of incubation for varying periods of time upon the amount of disease produced in wheat seedlings when inoculated with spore suspensions.*

Period of incubation hours	Infection ratings	
	Check %	Inoculated %
0	0.9	29.1
3	1.5	33.4
18	1.5	65.0
27	1.6	92.2
45	1.5	95.3

This test indicates clearly that a period of incubation after seed has been inoculated with a spore suspension of *H. sativum* results in a greatly increased degree of infection. Microscopic examination of pericarps stained with acid fuchsin showed that most of the conidia had germinated. The germ tubes usually were short and much branched forming a closely matted network of hyphae. Several instances were noted where hyphae became established within the cells of the epidermis. It appears probable that the fungus establishes itself saprophytically in the bran layers of the seed. When sown in moist earth, it is able to start growth before the embryo. As the coleorhiza and plumule break through the protective seed coats they may be immediately exposed to a mass of vigorously growing fungous hyphae. That infection does occur in this way appears probable since many of the non-emerged seedlings had infected plumules which were only a few millimeters in length when killed.

The spore suspension method of inoculation was also used to inoculate wheat seed during the maturation period. For this purpose sheaves of green wheat were cut and sprayed thoroughly with spore suspensions of *H. sativum* and kept moist for a few days. Drying and maturation were completed under laboratory conditions. The threshed grain was tested in sterilized sand in the greenhouse. A fair degree of infection was obtained in this manner, but about 30% of the seedlings escaped infection. For this reason the method was not investigated further.

Discussion

Soil naturally infested with *H. sativum* would be preferable for many types of experimentation. In lieu of this several attempts have been made in Western Canada to establish root-rot gardens to which cultures of the causal organisms were added in an attempt to maintain the desired flora of pathogenes. As pointed out by Sanford and Broadfoot (*14*) the inocula of root-rotting organisms soon become vitiated after being placed in the soil. This has been the result of similar attempts to infest soil with *H. sativum* at this laboratory. Therefore it appears to be necessary under the climatic conditions of Western Canada to inoculate each time an experiment is sown.

In the inoculation of young seedlings of wheat with *H. sativum* the usual method is to place the fungus on the seed or along with the seed in the soil. One method involves the use of mashes made from grains or parts thereof on which the fungus is grown and which are added with the fungus to the soil. This is a very effective method of inoculation and high degrees of infection may readily be obtained. The weakness of the method appears to lie in the difficulty of producing similar conditions in the controls. The inoculum contains a quantity of bulky organic material which must of necessity modify the physical condition of the soil and the biological balance of the micro-organisms around the host plants. An attempt to approximate these conditions in the controls by the addition of an equal amount of sterile medium or sterilized inoculum has been shown in this paper to be injurious to the host plant, where the soil is not sterilized. Since no such injury occurred where the soil was sterilized it is probable that the soil fungi and bacteria grew rapidly on the sterile medium and injured the seedlings directly or through the production of toxic substances. Sterilization of the soil is not practicable for field work and it is not desirable for many types of experiments in the greenhouse. Therefore the use of a medium to be added to the soil with the fungus has a limited application. This method must be used probably in the case of fungi which do not produce conidia readily in culture. However it is preferable to avoid the use of sterile medium or sterilized inoculum in the checks if the soil is not first autoclaved.

The use of conidial suspensions in which the seed is soaked before being sown is a method which has much to recommend it. For convenience in seeding, especially for extensive experiments, the conidia may be dried on the surface of the seeds. This method permits the use of a seeder. It was found that the severity of the infection produced by a spore suspension of *H. sativum* on wheat could be greatly increased by incubating the treated seed for 18 to 27 hours at 24°C. Longer periods of incubation did not increase the disease proportionately and resulted in germination of the seed. Examination of seed after such treatment showed that the conidia had germinated, producing short, many-branched germ tubes, some of which entered the epidermis of the pericarp. The result is probably that the fungus is given a favourable start when the seed is sown, so that a large amount of mycelium is present around the plumule and coleorhiza as soon as they emerge through the pericarp.

As a result of the study it appears that the spore suspension method of inoculation on mature seed is suitable for many types of experimentation where it is necessary to induce seedling disease of wheat with *H. sativum*.

A fair degree of uniformity of infection may be achieved by standardizing the technique of inoculation. Such considerations as spore concentration, even distribution of moisture on the seed, controlled temperature, and uniform periods of incubation are important. Of these the moisture factor during incubation is the only one that offers any difficulty. Small quantities of seed may be placed in thin layers between filter papers in petri dishes. Larger amounts of seed require occasional stirring as the moisture tends to drain toward the lower layers, and the upper layers become too dry due to evaporation and imbibition. The age of the culture from which the spores are taken is important. For *H. sativum* the writer prefers two-week old cultures.

Summary

1. A study was made of methods of inoculation of wheat with *H. sativum* for the production of seedling infections.

2. The age of the culture when grown on oat-hull medium affects the degree of infection obtained in the inoculated seedlings. Young cultures up to two weeks produce maximum infection while older cultures produce progressively less disease with age.

3. The addition of sterile medium or sterilized inoculum to the checks resulted in severe injury to wheat seedlings causing non-emergence when used in unsterilized soil. No marked injury was produced in sterilized soil.

4. Seed treated with a spore suspension of the fungus was found on drying to give higher disease ratings than when sown while still wet. This was shown to be due to a period of incubation when the spores germinated before drying was complete. It was found that by increasing the period of incubation to eighteen or twenty-seven hours at 24°C. high percentages of infection could be obtained.

5. It is suggested that uniform inoculations may be obtained by this method if the technique is standardized.

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CURRENT PUBLICATIONS

EMPIRE JOURNAL OF EXPERIMENTAL AGRICULTURE

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The Journal will command a strong Editorial Board, including among others, Sir John Russell, Director of the Rothamsted Experimental Station, as chairman, Sir Rowland Biffen, Sir Daniel Hall, Sir Robert Greig, Sir Frederick Keeble and leading agricultural authorities in the chief countries of the Empire. Dr. E. H. Tripp, (formerly joint-editor of the *Journal of the Society of Chemical Industries*) 40, Trewsbury Road, Sydenham, London, S.E. 26, is Secretary and General Editor. Dr. E. S. Archibald, Director of the Dominion Experimental Farms Branch, is the Canadian representative on the Editorial Board.

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VENTILATION OF DAIRY BARNS IN QUEBEC[1]

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Prior to the beginning of this century ventilation of stables received surprisingly little attention from scientists. With the exception of Professor F. H. King's work, little was done, at least in North America, toward the securing of definite data concerning the movement of stable air, its relative humidity, or its rate of replacement. During the last fifteen years, however, much has been done to segregate the problems involved. Particularly notable is the work conducted by Kelley (*1*) of the U. S. Bureau of Agricultural Engineering, who conducted co-operative studies with and in many of the states of the Union and in Canada.

The amount of attention devoted in early studies to the carbon dioxide content of air is now regarded as unwarranted and it appears doubtful whether, even in a stable dependent for ventilation on mere leakage of air, the carbon dioxide could ever become a source of danger to the animals. Pure country air has a CO_2 content of about 0.04%, or 4 parts in 10,000. King (*2*) advises dilution of stable air with fresh air sufficient to keep the CO^2 content down to 0.15%. Very bad air may contain a CO_2 percentage as high as 0.7%; in fact Clarkson (*3*) found 1.23% of CO^2 in the air of an unventilated stable. According to Hill (*4*), an English experimenter, it is not CO_2 content of the air which produces the ill effects of lack of ventilation. Hill experimented with groups of students who were shut up inside an air-tight glass cage until the air became so badly vitiated that the occupants of the cage could not light their cigarettes. The cage was equipped with an electric fan to keep the air in circulation when desired and it was found that, with the fan in operation, no discomfort was experienced by the students even when the CO_2 content of the air rose to 4%, the oxygen content dropped to 10% and the wet bulb thermometer registered 85° F. When the fan was stopped, however, discomfort was quickly in evidence and the subjects of the experiment were soon in distress. It is peculiar, also, that when occupants of the cage were allowed to breathe fresh air from outside the cage through gas mask tubing it did not relieve the distress which followed the stopping of the fan in the cage. The outstanding feature of recent work, therefore, is perhaps the switching of attention from the CO_2 content of stable air to its moisture content, its circulation, and the maintenance of optimum stable temperatures.

Probably the first experimental work in stable ventilation in Canada was that conducted at the Ontario Agricultural College in 1901 by J. B. Reynolds (*5*), Professor of Physics. The system studied was patterned after that used in the holds of ships, the intakes consisting of long flues running from near the stable floor through the loft and roof of the barn where they terminated in cowls with vanes which kept them turned into the wind. The out-takes ran from the stable ceiling to the upper part of the loft. The

[1]A paper read before the Agricultural Engineering Group of the C.S.T.A. during the 12th Annual Convention at the Manitoba Agricultural College, Winnipeg, June 16, 1932.

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system did not operate as intended, however, the intakes very frequently acting as out-takes, reversing the system.

In 1905 Dr. J. G. Rutherford (*6*) described a ventilation system used since 1890 in his own stock barn. This installation was the fore-runner of the "Rutherford System" recommended by the Central Experimental Farm and well known throughout Canada.

In 1908 W. H. Day (*7*), successor to J. B. Reynolds at the Ontario Agricultural College, conducted some studies which comprised probably the first attempt at tests to ascertain the comparative effectiveness of different methods of ventilation. The important feature of these studies was analysis of stable air for CO^2 content; the results, however, were inconclusive. Measurements of out-take velocities made with an anemometer were evidently not given more than casual consideration.

In 1908 Professor F. H. King of Wisconsin University published his book (*2*) on ventilation. In this book Prof. King demonstrated an ability to apply the laws of physics to the problem of ventilation considerably in advance of perhaps any other worker of his time. With the aid of the work of Armsby of Pennsylvania and from experiments conducted at Madison, Prof. King evolved formulae of use in the calculation of the rate of air change per animal unit and per unit of time to maintain a given standard of purity of stable air. Though the original King system of ventilation is more elaborate and expensive of installation than would at present appear to be necessary, his deductions are the basis of design of thousands of ventilation systems in satisfactory operation today.

Concerning the development of the Rutherford system, it is an unfortunate fact that Dr. Rutherford left no written record of his experiments. The only description of the system by him seems to be a verbal one given as part of evidence before the "Select Standing Committee on Agriculture and Colonization" (*6*) for the Canadian Government in 1905.

There is no record showing that he made any measurements of the rate of air movement through a stable, or of the relative humidity and chemical composition of stable air. The opinions given by him seem to be based on long and close observation, the system having been in use in his stables for twelve years prior to the date of the above mentioned evidence. Though Dr. Rutherford did not make a scientific analysis of the factors entering into the problem of ventilation, the deductions from his evidence show that he had a very clear conception of physical principles involved. In the light of the findings of this study it is interesting to note that Dr. Rutherford recommended regulation of the rate of air change by varying the size of the opening into the out-take flue rather than by means of the intakes. It is also interesting that the out-take area per mature animal in use in the system in his own barn was about 29 sq. ins. This is in very close agreement with Prof. King's recommendations.

About 1905 Dr. Rutherford turned the development of his ventilation system over to the Central Experimental Farm at Ottawa and in his first report (*8*) on the subject in 1908 Dr. Grisdale recommended an out-take area of 6 to 8 square inches per head, though for small stables an increase in area of from 25 to 100% was recommended. In 1914 (*9*) the recommendation

of the Central Experimental Farm was changed to "15 square inches or more" of out-take area per head. However, even with this increase in out-take area the recommended capacity of the Rutherford system was only slightly over 50% of the area used by Dr. Rutherford in his own stable. The reason for this reduction in capacity is not clear but it may explain why so many barns which are equipped with the Rutherford ventilation system are under-ventilated and may have something to do with the disfavor into which the Rutherford system has fallen among the inspectors of the Department of Health of the City of Montreal. The existence of this prejudice against the Rutherford system was one of the factors responsible for the studies undertaken by the writer in 1928.

Naturally, farmers who had followed the advice of the Provincial or Dominion Departments of Agriculture or that of Eastern Canadian Agricultural Colleges, who had installed Rutherford systems and were then obliged to replace these with a King type system were both confused and chagrined. It was plainly evident that some form of comparative study of the two systems of ventilation should be undertaken.

The Island of Montreal, though only some ninety miles in circumference, is the home of about one and a quarter millions of people. This city and its suburbs form Canada's largest single market for fluid milk. Dairy farming, therefore, is the most common type of farming for a radius of perhaps fifty miles from the city. From the writer's location on the western end of Montreal Island he is within easy reach of a considerable number of dairy barns. Most of these are modern barns, much better in design and construction than the average, and among them are good examples of the two prevailing types of ventilation equipment—the Rutherford system and the modified King system, which will be referred to as the "Single Out-take King System."

From amongst a number of barns visited in the fall of 1928 seven of each of the two types of ventilation mentioned were selected for special study.

The Single Out-take King System

This system of ventilation is similar to the standard King system only in that the incoming air is admitted at the stable ceiling and the out-going air enters the flue through an opening in one side at the bottom of the shaft. The following are the distinctive features of the system:—

1. There is only one out-take flue in the stable and its cross section area provides about 26 square inches of out-take area per animal unit.

2. The out-take flue is generally located at one end of the stable; it is square or nearly so in shape and is run vertically through the roof to a ventilator head consisting of no more than four corner posts and a roof.

3. The out-take flue is closed in to the floor on three sides, an opening equal in area to the flue area being provided at the bottom of the fourth side. This is provided with a control slide hung by a rope and pulley with a counter weight on the other end of the rope.

4. Air is brought in through openings in the wall, located just above the floor, and conducted up to the ceiling through small flues of from 40 to 50 square inches cross section area. These flues open into the stable within a few inches of the ceiling and the openings are fitted with hinged covers.

Figure 1. A typical installation of the "Single Out-take King System" of stable ventilation.

5. Intakes are built as above described regardless of the direction in which cattle are facing.

6. Total intake area recommended is usually 75 to 80% of the total out-take area.

Inquiry to ascertain how or by whom this system of ventilation was introduced revealed the fact that it was first recommended by Cassius Way, D.V.M., while an inspector of the Borden Milk Products Company.

Object and Methods of Study

The object of this study was of a two-fold nature:(1) To discover and measure any differences in effectiveness and operation between the King and Rutherford types of ventilation systems. (2) To collect data needed in the improvement of construction of dairy barns and their ventilation systems.

The results of isolated tests of ventilation in barns made prior to the planning of this work clearly indicated that conclusions as to the comparative effectiveness of these two methods of ventilation should not be based on results secured in one or two barns. For instance, measurements of air movement, relative humidity and temperatures found in one barn were nearly the same as those from another yet the walls and ceiling of the first barn were dry while on those of the second considerable condensation was in evidence. Again, in one barn the performance of the out-takes of a multi-out-take Rutherford system was much more erratic and irregular than that of a similar system in another barn; or, in one barn some out-takes had to be kept closed in cold weather, due to back-drafting, while in others peculiarities of a different nature were noted.

Because of peculiarities such as these and others which affect the performance of a ventilation system in one barn but which would not apply to

all such structures it seemed advisable to make the study include a sufficient number of barns and tests to make possible the deduction of average trends and the elimination of extreme results. Of the barns selected for study structural data including cubic content per animal unit, number and sizes of doors and windows, wall and ceiling construction and insulation were collected, also a complete record of the nature and construction of the ventilation equipment.

Performance Studies

During the visits to the barns the following measurements and observations were made.

1. *Out-take air velocities.* These were made with a Biram registering anemometer. In Rutherford out-takes the readings were taken about a foot from the mouth of the flue and in the single out-take King flues they were taken in the aperture. This type of out-take, open on one side only, and with its slide controlled aperture is very well adapted to the taking of these measurements. Apertures were cross sectioned and readings of 30 seconds duration taken in each section. The mean was then taken from these readings and multiplied by the area of the aperture to secure the volume of air moved per unit of time.

2. *Relative Humidity.* These measurements were made with a standard sling psychrometer and repeated sufficiently frequently to secure well checked records.

3. *Temperatures.* These were taken at elevations about two inches from the floor and ceiling by weather bureau thermometers while the "mid-height" temperatures recorded were the dry-bulb readings of the sling psychrometer.

Figure 2. Using ammonium chloride fumes to trace air movement in a stable. Note the gas cloud moving from the wall to animals.

4. *Out-take Air Temperatures.* In order to estimate the heat removed in the out-going air of each of the two types of ventilation, temperatures of the air stream were taken by means of a thermometer tied to a stick and held in the air stream until constant readings were secured.

5. *Air Movement.* To trace the course of incoming air, as well as the behaviour of convection currents of air, ammonium chloride fumes were liberated into the air. The apparatus used was that devised by Professor F. L. Fairbanks, Department of Agricultural Engineering, Cornell University. The apparatus was fastened to a rod 5 feet long making possible

the liberation of fumes into the air stream wherever information concerning air movement was desired.

6. *Wind Records.* A Robinson registering wind gauge was fitted on a tripod and set in an open space near the barn. It was not the intention to study the effect of wind on the operation of the ventilation system, therefore only approximate data concerning wind were considered essential. Most tests, in fact, were conducted on comparatively calm nights, so as to minimize, as much as possible, the influence of the wind.

Comparative Analysis

A study of the data gathered shows that both the King and the Rutherford types of ventilation are effective in bringing about a sufficiently rapid rate of air change to produce good stable conditions. Stable conditions which must be described as good and mediocre can be found among both types of installations, but in cases of failure or partial failure the cause is usually one of the following conditions or a combination of two or more of them:

1. Insufficient flue capacity.
2. Too high a cubic content per A.U. (Animal Unit) or understocking the stable.
3. Lack of insulation in walls and ceilings to permit maintaining of the necessary temperature difference for good stable conditions in cold weather.
4. Air leakage through walls and ceilings and failure to equip stable with double doors and windows.

It is a justifiable conclusion to say that until an observer has made the necessary tests to show whether or not a given installation of either type is effecting the necessary rate of air change he should not condemn the ventilation system. When the physical forces upon which both systems depend for their operation are present in a stable it is obvious that either system must work. The most important of these forces is the difference in density between the inside and the outside air, the former being lighter because of its higher temperature. There is set up thereby a lower atmospheric pressure inside the stable than exists outside. This results in a continual flow of air from the high to the low pressure side of the walls and ceiling, causing a continual displacement of the warm by the colder air so long as there is any provision for the escape of the warm air. Wind suction, as it blows across the open tops of flue outlets, influences the rate of air change and so does wind pressure on the windward side of the building, but wind is a disturbing rather than a helpful force and should be considered from the standpoint of operation of a ventilation system rather than from one of design.

An examination of Table 1 shows that both systems in these groups of barns are effective in producing ventilation. It is evident, in fact, that the best air conditions are found in the Rutherford group of barns. The St. Sulpice barn, for instance, shows a midheight temperature of 60°F. and a relative humidity of 66%, and this with a recorded rate of air change of only 38 cubic feet per minute and an outside temperature of 10°F. Inside temperatures in the Rutherford group generally are higher than those of the King group but there are two factors which have an influence on this difference.

First, there is the fact that the outside mean temperature during the tests in the Rutherford group is 11.31°F. while that for the King group is 2.57°F., and secondly, it happens that the construction of the walls and ceilings of the Rutherford group is much heavier than that of the King group.

The data collected make it plain that it is possible to have all the ventilation the stock housed can support and yet have wet walls and ceilings. In such cases the treatment indicated is not more ventilation but more insulation.

Table 1 also has some interesting data as to when a stable may be considered to be well ventilated. The barns included in these two groups are exceptionally well equipped with ventilation facilities, and other conditions affecting the comfort of the animals housed are better than the average. A rate of air change of 50 cu. ft. per A.U. per min. is evidently sufficient for the maintaining of good stable conditions. Mean midheight temperatures under winter conditions are about 52.7°F. and the relative humidity just under 75%. According to some men who have long experience in intensive, year round dairying, however, in these groups of barns, the dairy stable should have a mid-height temperature of not less than 58°F.

Comparative Efficiency in Heat Conservation

The securing of data permitting the determination of the amount of heat per unit quantity of air handled by the two types of out-takes was one of the important objectives of this study. For this purpose air stream temperatures were taken and recorded in Table 1.

In order to keep the data from the two groups of barns on a comparative basis only the total heat contained in a unit quantity of air removed by each system was taken into consideration. Relative humidities recorded are for midheight temperatures and in calculating total heat of the air removed it is assumed that the absolute humidity is practically the same throughout the stable.[3]

From Table 1 it will be seen that the mean of the out-take air stream temperatures for the Rutherford group is 53.6°F., or 2° lower than the mean ceiling temperature. The mean of the out-take air stream temperatures for the King type flues is 48.5°F. The mean ceiling temperature of this group of barns is, however, 1° below that of the Rutherford group while the mean of the floor temperatures is 0.95° lower. In order to make the heat losses of the two groups comparable they should be dealt with as though they had the same amount of total heat per pound of air at the ceiling. Or, it seemed desirable, in making this study, to ascertain what would be the heat loss per pound of air removed from the Rutherford group had this air been removed through a floor outlet instead of one at the ceiling. To make this possible the mean air stream temperature of the King group was raised 1°, or from 48.5° to 49.5°F.

On this basis the total heat of each pound of air removed by the Rutherford group is 20 B.T.U., while that of each pound removed by the floor out-takes of the single out-take King group is 18.2 B.T.U. Or, for each pound of air removed by a floor out-take the conservation of heat is equal to 1.8 B.T.U. over that removed by a ceiling out-take.

[3] Calculations were made with the aid of Humidity Charts of W. H. Carrier in "Fan Engineering."

TABLE 1.—*Temperatures taken outside of barn, at ceiling, midheight, floor and in the air-stream; also relative humidity, in representative barns of Rutherford and single out-take King barns.*

Names of Barns	Temperatures					Per cent relative humidity	Air change Cu. ft. per A.U. per min.	Out-take Area per A.U. Sq. Ins.
	Outside	Ceiling	Mid-Height	Floor	Air Stream			
Rutherford Systems								
Macdonald College	−10	50	46	43	48.5	72	45.3	21.7
	14	54	50	48	49	75	58	21.7
Raymondale Barn	19	52	51	48	51	79	58	28.3
	15	58	56	52	56.5	78	47.3	10.6
Mount Victoria Barn	19	54	48	47	53	74	93	26.8
	14.5	55	52.5	48	53	78	68	26.8
Hadley Barn	9	60	57	54	59	77	35	11.1
St. Sulpice	10	62	60	57	59.5	66	38	11.8
Single Out-Take King Systems								
Mercroft Barn	14	60	59	52	55	72	49.3	30 (a)
	2	64	59	57	56.5	80	43	30 (a)
Skinner Barn	−10	48	49	45	46	74		59 (a, b)
	4	49	48	44	46	74	47	59 (a, b)
Maxwell Barn	6	53	51	48	47	75	50.5	29
	7	48	44.5	43	43	80	56	29
Armstrong Barn	11	60	54	52	46	78	47	17.8
Means								
Rutherford Group	11.31	55.6	52.8	49.65	53.6	74.9	55.36	19.85
Single Out-take King Group	2.57	54.6	52.1	48.7	48.5	76.43	48.8	23.1

(a) Operated about one third open.
(b) Only half of area allowed in mean.

Considering 50 cu. ft. of air per A.U. per minute as a normal rate of air change the ceiling out-take would remove 50 ÷ 13.05 x 20 = 76.6 B.T.U. per A.U. per minute. The floor out-take would remove 50 ÷ 12.95 x 18.2 = 70.25 B.T.U. (The quantities 13.05 and 12.95 are the number of cu. ft. per pound of air at the temperatures and relative humidities of the air leaving by ceiling and floor out-takes respectively.)

The floor out-takes, therefore, conserve, at the above rate of air change, 76.6 − 70.25 or 6.35 B.T.U. of heat per A.U. per minute. In 24 hours this will amount to a saving of 9144 B.T.U. or 12.47% of the estimated heat production per A.U. which is about 73,300 B.T.U. (*10*).

This is sufficient heat to raise the temperature of 8.2 cu. ft. of air per minute from 10° to 50°F. or 16.3% of the requirement of 50 cu. ft. per A.U. per minute. In our climatic conditions this conservation of heat is well worth while and the ability of the floor out-take to make this conservation is an important factor in its favor.

Figure 3. Air movement diagram typical of a two row stable. Note location of out-take flue, also of intakes.

General Conclusions

Analysis of the data collected indicates the following conclusions concerning the design and operation of ventilation systems.

1. Out-take facilities can be concentrated to good advantage in a single flue; this is true even for exceptionally large stables.

2. Under normal winter weather conditions, a rate of air change of 50 cu. ft. per min. per A.U. (1000 lbs. live weight) is sufficient.

3. The circulation of stable air is caused by the animals in it rather than by the ventilation system. Convection currents are stronger than the pull of the out-take flue excepting within a radius of about 2½ feet from the mouth of the flue. Rows of stanchioned cattle set up very definite and strong convection currents from animal to ceiling, to the nearest cold wall, to the floor thence back to the animal (see Figure 3). There is also present, in litter alleys and feed alleys of considerable length, another current lengthwise of the passage way in one direction along the floor and in the opposite direction along the ceiling.

Circulation in parts of stables given over to box stalls is usually much inferior to that among stanchioned stock. These sections of stables are usually colder and often give indications of sluggish air circulation. The remedy would appear to be to keep such sections well filled with stock and to pay particular attention to insulation of walls and ceilings, also to provide slots or holes for air circulation near the bottoms of box stall walls.

4. While concentration of out-take has no harmful effect concentration of intake is not permissible. Intake flues must be well distributed around the stable and a total intake area of 75% of the out-take area appears satisfactory. In operation all intakes should be kept open at all times except in cases where excessive wind pressure causes excessive intake velocities. Even then, they should not be entirely closed. Making covers of intake openings 1 inch short is a good preventative.

5. The rate of air change through a stable should be controlled by regulation of the out-take aperture. This study has shown that the rate of air change depends on the amount of air the out-take is allowed to handle. Air leakage through accidental openings in walls and ceilings will usually

supply more air than the permissible rate of change in cold weather if the out-take capacity is not controlled. In many tests out-take velocities remained practically the same whether the intakes were open or closed. In multi-out-take systems, however, closing of all intakes caused back-drafting through one or more out-takes.

6. The place of intake flues is to bring about even distribution of incoming air and to prevent excessive intake velocities. Intake velocities should be so low that the incoming air will settle to the floor almost vertically as it unites with the down flowing convection current. Stables without proper intake equipment are usually subject to serious drafts due to the high velocity of air coming in under doors and other accidental openings.

7. Wet walls and ceilings, almost universally accepted as indicators of poor ventilation, can be prevented by more insulation more frequently than by increased ventilation. Filling spaces between studs with dry planer shavings or sheeting the inner surfaces of stable walls with commercial insulating board will not only prevent condensation on these areas but will improve the operation of the ventilation system.

The Superiority of Single Out-take Systems

As is frequently the case in the results of research work, the by-products of this study are perhaps of greater importance than the problems the study was planned to solve. While the King type systems studied employ the principle of the true King system in that the air is admitted at the ceiling level and removed from near the floor, they were not multi-out-take systems, such as King prescribes, but each stable was served by only a single out-take.

It did not require many tests to bring out the evident superiority of the single out-take to the multi-out-take systems. Air flow through the single

Figure 4. View of single out-take flue located at the intersection of two wings of an "L" shaped stable. Flue is open on one side only which makes for easy and positive control of rate of air change.

out-takes was more constant and at a much more uniform rate. In typical multi-out-take systems the performance was always more or less capricious, variations in the performances of the various flues of a system changing with almost every change in the direction of the wind. No such vacillations occurred with single out-takes in any instance. In multi-out-take systems there were repeated instances of back-drafting in some out-takes, especially so when the operator was inclined to close too many intakes, which action is, of course, easily understood. There was not one instance of back-drafting in a single out-take system.

Even in very large stables single out-takes are superior in their action. The Skinner barn with a capacity of over 80 head, and "L" shaped in plan was equipped with two out-takes, the milk inspector who prescribed the system evidently fearing a single out-take for the whole structure would not suffice. That for the main stable is 4½ by 5 feet, while that for the south wing is 3 feet square. It was not long, however, before the stableman noticed back-drafting from the smaller flue. It was kept closed for a few days and several tests made. Relative humidities and temperatures were uniform through the whole stable. There was, of course, plenty of out-take area in the larger flue to serve the whole stable population which made the smaller flue unnecessary. The superiority of single out-take systems seems also to apply to the ceiling type of out-take or those of the Rutherford system.

The advantage of single out-take ventilation systems can be summarized as follows:

1. *More Positive Action.* Single out-takes will not back draft under normal conditions. In very tightly built barns closing of intakes may cause a slowing down of out-take velocity but will not cause back-drafting.

2. *Greater Efficiency.* Anemometer readings in small and large out-takes of the same stables showed that the air stream velocity in large vertical flues sometimes was almost double that of small out-takes. The efficiency seems to increase very rapidly with increase in cross section area until the smallest dimension of the flue reaches 18 inches. In one barn the old system consisted of 4 pairs of "split" type out-takes, each leg of which was 10 by 14 inches. A 20 inch square flue was installed in one wing not very well ventilated. Velocities as high as 745 feet per minute were measured in the large flue while the average of the velocities of 4 of the small flues was 345 feet, measurements being separated by only a few minutes. The larger flues also permit less heat loss from the out-going air. This is due to the more favorable cross section area and perimeter ratio.

3. *Simplifies Design.* Where only fairly large out-takes are employed a much greater similarity of performance can be expected between different systems. One of the baffling things in multi-out-take systems with very small flues was the disappointing performance of the installation when compared to that of others with no greater total out-take area but fewer and larger out-takes. Locating one out-take so as to miss the hay-tracks and keep it out of the way generally is a much less difficult problem than is the design of a multi-out-take system. In many instances they are located outside the building, the opening into the flue being a hole cut in the wall. Such flues, of course, call for extra heavy insulation.

4. *Economy of construction.* The bill of material for the out-take flues of a system varies almost as the sum of the perimeters of the flues and the labor cost varies very nearly as the number of the flues. Thus a system calling for 9 square feet of out-take area will require a flue 3 feet square having a perimeter of 12 feet. The same out-take area supplied by a 3-out-take system would require 3 flues, each 20.8 inches square. The sum of the perimeters of these flues is 20.8 feet making an increase of 73% in the bill of material. Then there is only one hole in the roof and one ventilator instead of three. These items are of great importance to the farmer who has to pay for the installation.

5. *Ease of Regulation.* The amount of air a given out-take will remove from a stable is governed by the capacity of the flue and the size of the aperture. To cut the capacity of a given flue by one-half it is necessary to reduce the size of the aperture into it to about one third of the flue's cross section area. Such regulation calls for a device through which small adjustments can be accurately made. The counterbalanced slide is much superior for this purpose to the butterfly valve type of damper. When only one aperture with a convenient slide has to be looked after, regulation of the system becomes very simple.

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CURRENT PUBLICATION

DER EINFLUSS DER HANDELSDUENGER AUF DAS PFLANZENWACHSTUM UND AUF VERSCHIEDENE EIGENSCHAFTEN LALKARMER MINERALBOEDEN. Schmitt, L. (The influence of commercial fertilizers on plant growth and different properties of mineral soils) published: Verlagsges; fuer Ackerbau; Berlin; 1932; pp. 188; 12 plates; 20 graphs. RM. 9- ($2.50).

As the results of the fundamental investigations into the problem of soil acidity became more widely known, many workers began taking an interest in the question of the physiological reaction [pH values?] of commercial fertilizers. Generally, pot culture experiments were resorted to for this purpose. Recent researches rather tended to prove these containers to be inadequate, especially when artificially prepared soils were used. Even the few field experiments which dealt with the influence of commercial fertilizers on soil reaction did not materially add to our knowledge; they were either carried on in unsuitable soils or for such brief duration only, that often most misleading data were obtained.

It is, therefore, to be welcomed anywhere where the question of soil fertility is of interest, that the data in the above 'treatise' have been made available through publication. They represent, we are told, the results of a considerable number of long-continued field experiments conducted under the [official] auspices of the Darmstadt, Germany, Agricultural Experiment Station.

While different investigators inclined to the view that potash fertilizers—principally on the basis of their "pot- and solution-cultures"—were to be considered as "physiologically acid", the field experiments discussed in the first section of this interesting publication rather indicate that these salts, under practical conditions of field experiments, reacted physiologically neutral.

By means of numerous investigations of consistently and uniformly fertilized experimental areas, in regard to reaction and retention, as well as in regard to lime conditions generally, it was possible to confirm this contention at the close of the fifth experimental season.

In the potash series it was indeed remarkable that a Kainite, poor in magnesia, should, on experimental soils of "high convertible acid contents" and without the least application of lime, yield the most satisfactory harvests, in the majority of cases, indeed, higher than those receiving other potash salts plus lime.

Then follows an attempt to solve or at least explain, the cause of this condition and "culture pot" and further field experiments were resorted to. The explanation offered is briefly that the magnesium ion is capable—in acid mineral soils, without any change in the degree of reaction—of producing a completely normal growth.

The third section deals with results obtained from 6 to 9 and 30 years field experiments by the Darmstadt Station, thus furnishing a prominent contribution to the comprehension of the question of the physiological reaction of acid phosphates. In opposition to the constancy with which it has been believed, that superphosphate produces a physiologically acid reaction, these experiments, it is shown, provide ample proof of the fact that this fertilizer—equally to di-calcium phosphate—is really of the type of physiologically perfectly neutral fertilizers.

The next section is devoted to the physiological reaction as a result of applications of nitrogenous fertilizers. In all the Darmstadt experiments, during the duration of which a steady increase in the degree of acidity had been noted and determined by a continuous study of the reaction, the potash and phosphoric acid fertilizers did not prove responsible for this increasing acidity of the experimental areas, but rather the strongly "Physiologically acid reacting" ammonia sulphate. While this nitrogenous fertilizer under neutral and lime deficient conditions caused from year to year increasingly prominent injury to plant growth, sodium saltpetre, similarly to calcium nitrate, however, proved most efficient—even in the absence of lime applications—and without causing at the same time an appreciably more favourable soil reaction.

Thus—it is stated—proof has been furnished that even under natural, practical conditions the results follow the same rules in regard to nitrate ion absorption in the presence of acid reaction of the substratum, as has been shown by "cultural solution" experiments carried out by Prjanischnikov.

The fifth section deals with graphically illustrated explanatory calculations relative to the "per cent" effect of lime applications in the experimental series; these again emphasize that applications of lime to naturally lime deficient soils play a decisive role, without which it is not possible to secure totally satisfactory returns from potash—phosphoric acid—nitrogen fertilizer applications.

These brief observations may suffice to illustrate the scope and nature of the book, which is a most noteworthy contribution to our understanding of the physiological effects of commercial fertilizers and I agree with Professor Roessler who favours the author with a prefatory notice which he concludes as follows: "Since the soil is the most costly heritage, which a people possesses, researches aiming at the conservation of its fertility even for times to come, should prove of utmost value to their economic existence." This too, is true for Canada. H. T. Gussow.

RESUME DES ARTICLES PUBLIES EN ANGLAIS DANS CE NUMERO

PROGRAMME D'ORGANISATION DES FERMES DE LA COLONIZATION FINANCE CORPORATION. F. W. Reinoehl, Chief Farm Manager, Colonization Finance Corporation, Winnipeg, Man.

La Colonization Finance Corporation est composée des représentants de neuf sociétés de prêt de l'Ouest du Canada et rescoit aussi la coopération du Chemin de Fer Canadian Pacifique.

La Corporation a pris à son service comme directeurs de zone plusieurs des meilleurs techniciens des Provinces de l'Ouest recrutés parmi le personnel des collèges, des services de propagande agricole, et de certaines organisations commerciales. La corporation cherche à protèger ses propres intérêts financiers en améliorant la situation technique des cultivateurs sur lesquels les hypothèques lui donnent quelque contrôle.

L'auteur esquisse les principes généraux d'organisation de la production agricole dans l'Ouest. Dans une région suffisamment compacte environ 80 propriétés peuvent être surveillées par un seul homme. Le coût supporté entièrement par la société intéressée est de moins de 20 cents par acre.

L'auteur fait ressortir la différence entre ce genre de surveillance et le travail de propagande fait par le Gouvernement et ses représentants agricoles. Les deux systèmes sont complémentaires et ne peuvent se remplacer mutuellement.

ROLE DE LA VITAMINE D DANS LA NUTRITION DES PORCS. R. D. Sinclair, Université de l'Alberta, Edmonton.

L'auteur rapporte une série de 5 expériences quant aux effets de la vitamine D sur l'assimilation du calcium et le maintien d'un équilibre entre le calcium et le phosphore suffisant pour prévenir le rachitisme. La lumière solaire, la radiation artificielle ou l'huile de foie de morue comme sources de vitamine D combinées à l'addition de calcium à la ration de base ont prévenu la raideur, augmenté la croissance et diminué les besoins nutritifs.

QUELQUES OBSERVATIONS SUR LES VARIATIONS EN QUANTITE ET EN QUALITE DES CENDRES DE POMMES WAGENER EN NOUVELLE ECOSSE. Dr. W. A. DeLong, Acadia University, Wolfville, N. E.

Les résultats de trois ans d'études sur la teneur en matières minérales de pommes Wagener indiquent que la quantité totale de cendres et la proportion des diverses matières minérales peuvent être influencées par l'application de certains engrais chimiques en quantités commerciales. L'application continue de nitrate de soude seul baisse la quantité totale de cendres en comparaison avec des arbres voisins ne recevant pas d'engrais chimiques. Dans ce cas les proportions de potasse et de phosphore sont aussi notablement inférieures à ce qu'on trouve dans les fruits provenant d'arbres non fertilizés. Des effets similaires suivent l'application de chaux seule en ce qui concerne la quantité totale de cendres et le pourcentage de potasse. D'un autre coté des applications repétées de muriate de potasse seul augmentent de beaucoup la quantité totale de cendres et le pourcentage de potasse dans le fruit. L'effet du superphosphate ou des scories est beaucoup moins prononcé; il y a probablement une légère augmentation de la teneur des cendres en phosphore.

Une étude comparée a été entreprise de la quantité de cendres dans le fruit, des quantités d'engrais chimiques appliquées et des qualités de conservation des fruits. Il n'est pas encore possible d'annoncer de résultats definitifs mais des indications intéressantes ont déjà été obtenues.

UNE MALADIE DU BLE REWARD ANALOGUE AU BLACK CHAFF. W. B. Broadfoot et H. T. Robertson, Laboratoire fédéral de pathologie végétale, Université de l'Alberta, Edmonton.

Les auteurs ont observé que les glumes de blé Reward prennent parfois une coloration rappellant à l'examen superficiel la maladie connue sous le nom de Black Chaff, causée par le *Bacterium translucens undulosum* décrit par Smith. Dans certains cas il est difficile de déterminer si les glumes noires sont dues au Black Chaff ou non.

Des études culturales et histologiques semblent indiquer que certaines lignées de blé Reward et quelquefois même de blé Marquis possèdent des facteurs héréditaires de couleur qui produisent des surfaces de pigmentation foncée dans des conditions d'intensité lumineuse convenables. Si tel est le cas, la plupart des lignées du blé Reward qui produisent actuellement des glumes foncées continueront de le faire, l'intensité du phenomène dépendant de certaines conditions de milieu et notamment de la lumière.

METHODES D'INOCULATION DU BLE AVEC HELMINTHOSPORIUM SATIVUM P.K. ET B. B. J. Sallans, Laboratoire fédéral de pathologie végétale, Université de la Saskatchewan, Saskatoon, Sask.

L'auteur discute la meilleurs façon d'inoculer le blé avec *Helminthosporium Sativum* P. K. et B. pour produire de jeunes plantes infectées.

VENTILATION DES ETABLES. Farmers' Bulletin No. 5, Collège Macdonald, P.Q. L. G. Heimpel, Chef du Département du Génie Rural, College Macdonald, P.Q.

Le Professeur Heimpel recommande l'emploi d'un nouveau système de ventilation connu sous le nom de "Single Out-Take King System", (Système King à cheminée de sortie unique) parce qu'une seule cheminée de sortie est suffisante, même dans les très grandes étables. Ce système modifié assure une meilleure ventilation tout en réduisant les frais d'installation à moins de la moitié du coût des anciens systemès King et Rutherford à nombreuses cheminées d'évacuation. Les recommendations faites dans ce bulletin sont appuyées sur les résultats de plusieurs essais comparatifs faits avec les systèmes de ventilation du type Rutherford et du système King à cheminée de sortie unique, et cela dans une quinzaine d'étables où l'on produit du lait pour l'approvisionnement de la ville de Montréal. Ces essais fournissent les données suivantes.

(*a*) Taux du renouvellement de l'air dans l'étable.

(*b*) Température au niveau du plancher, du plafond et intermédiaire.

(*c*) Mouvement de l'air dans les étables.

(*d*) Degré d'humidité relative de l'air constituant une indication importante de l'efficacité d'un système de ventilation.

(*e*) Volume d'air disponible par vache et par unité animale.

(*f*) Détails sur la structure ayant une certaine influence sur les pertes de chaleur du local et sur le maintien des murs à l'état sec.

Ces données démontrèrent que, bien que la ventilation soit essentielle pour maintenir l'atmosphère des étables saine, on ne peut s'attendre qu'elle soit un remède contre la condensation de l'humidité sur les murs et les plafonds de nombreuses étables. Dans maints cas, il faut non seulement avoir un bon système de ventilation mais aussi construire les murs et les plafonds avec un bon matériel isolant. Les indications nécessaires sont aussi données dans ce bulletin sur la construction, le règlage et la conduite de ce système.

CONCERNING THE C.S.T.A.

PROFESSIONAL FARM MANAGEMENT

In this month's issue of *Scientific Agriculture* we present an article on a phase of agricultural economics which has heretofore received little publicity in Canada. Professional farm management has grown to a considerable extent in the United States in the past ten years. In the states of Indiana, Illinois and Missouri alone there are fourteen organizations undertaking to provide farmers with management service. Six of these organizations are privately owned and eight are associated with a bank or some other organization.

The corporation farm management idea is not a child of the acute phases of the depression. Mr. Reinoehl points out that the work in western Canada was undertaken to improve mainly farm properties that had come to grief previous to the low prices of 1930 and 1931. The movement should not be judged on its ability to salvage marginal land or to stem the tide of a world-wide depression; that is not its purpose. It can materially improve the lot of those who through personal misfortune or mismanagement find themselves in a position where they are willing to accept a certain amount of direction. From the point of view of the company or the individual holding the mortgage, a professional farm management service protects the investment.

The interesting point which comes to mind is how present conditions will affect the movement. Farm mortgages of late years have tended to concentrate in the hands of investment corporations and government farm loan boards. Will it be necessary eventually for these institutions to place a certain proportion of their properties under the direction of farm managers. There are good properties being farmed by very poor farmers and good farmers on very poor properties. In the interests of national economy a policy of supervision in placing tenants, selling farms, and managing farms would seem to be reasonable.

NOTES AND NEWS

G. W. Muir (McGill 1914) has been appointed Dominion Animal Husbandman, succeeding Mr. G. B. Rothwell who became Live Stock Commissioner last year. Mr. Muir is a native of St. Laurent, Quebec, and acquired his early training in live stock on the farm of R. R. Ness where previous to and during his college course he received valuable experience with Ayrshire cattle and Clydesdale horses. From 1914 to 1920 he was Assistant Animal Husbandman at the Central Experimental Farm, Animal Husbandman from 1920 to 1926, and Chief Assistant from 1926 until he became Acting Animal Husbandman in 1932.

W. F. Stephen has resigned as Secretary-Treasurer of the National Dairy Council, rounding out half a century of service for Canadian agriculture. Following his early training in Huntingdon Academy and McGill Model School he proceeded to build up an Ayrshire herd considered one of the best in the country in its day. He became a director of the Quebec Ayrshire Breeders Association at an early age, and while showing his herd at the World's Columbian Exposition in Chicago in 1893 was one of the leaders advocating the amalgamation of the Ontario and Quebec Ayrshire Breeders Associations. Following this amalgamation five years later he became President of the Association and later became Secretary. Between 1906 and 1927 he built up the Ayrshire Association from a membership of about two hundred and fifty to over sixteen hundred. He started the *Canadian Ayrshire Review*, now widely known as the official organ of the Association. Mr. Stephen was also interested in herd improvement and was one of the committee which formulated the Advanced Registry out of which developed our present Record of Performance system. He was also actively associated with the dairy industry in general and was Secretary of the Montreal Milk Producers Association for a number of years. In 1927 he became

Secretary-Treasurer of the National Dairy Council, a position in which his practical background and wide knowledge of Canadian conditions have been valuable to the industry. Mr. Stephen will reside in Ottawa where he will continue to take an active interest in agricultural affairs and do some journalistic work.

JUDGING WORLD'S GRAIN EXHIBITS

The work of judging the thousands of samples entered in the competitive classes of the World's Grain Exhibition and Conference is already under way. The greatest care is being taken to preserve the identity of every exhibit entered and to prevent interference in any way. The samples are all housed under lock and key in a judging room specially set aside for the purpose in the immense building in which the exhibition will open on the 24th of July next.

Drawing seed samples in the World's Grain Exhibition Building, Regina, Saskatchewan. Mr. W. H. Wright, Chief Seed Analyst, Dominion Department of Agriculture, in the foreground.

The sampling committee has already commenced the drawing of a small quantity of seed from the cereal and flax entries for the purpose of growing tests. This committee is composed of officials of the Federal Department of Agriculture connected with the Entomological Branch, the Rust Research Laboratory at Winnipeg, and the Dominion Seed Branch. This preliminary work is being done under the direction of Mr. Nelson Young, district inspector for the Dominion Seed Branch.

All samples are being examined for insect pests and plant diseases. Some will be sent to the office of the chief seed analyst of the Dominion for the purpose of determining the weight per measured bushel and the thousand kernel weight.

Cereal crop and flax growing tests will be conducted on experimental farms at Morden (Manitoba), Indian Head (Saskatchewan), Harrow (Ontario) and on the Central Experimental Farm at Ottawa.

All exhibits are being sampled for various purposes. When the findings are completed the records will be forwarded to the World's Grain Exhibition and Conference management for compilation. The results will be considered when the exhibits are finally judged by an international board of judges.

Although it is necessary to secure over 10,000 samples the work will be completed in sufficient time for the spring seeding for growing tests. These growing tests are for the purpose of checking up on purity of variety type as each exhibit is required to bear its variety name.

Cereal producing countries are quite well represented in the competitive classes as exhibits have come from England, Scotland, Northern Ireland, Germany, India, Burma, The Philippines, Siam, Southern Rhodesia, South Africa, New Zealand, British Guiana, Victoria, Queensland, New South Wales, West Australia, South Australia, 24 states of the United States and all of the Canadian provinces.